Kenneth T. Deschler

Cable Television Technology

Sponsored by the Electronic Industries Association

J. LUKOMSKI

Kenneth T. Deschler

Cable Television Technology

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TO MY FATHER, KARL, AND MY MOTHER, MARY, WHO ENCOURAGED BOTH INDEPENDENT THOUGHT AND SELF-CONFIDENCE IN ALL THEIR CHILDREN.

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SERIES PREFACE

Electronics is at the core of a wide variety of specialized technologies which have been developing over several decades. Challenged by rapidly expanding technology and the need for increasing numbers of technicians, the Consumer Electronics Group Service Committee of the Electronic Industries Association (EIA), in association with the Voorhees Technical Institute, Oklahoma State University, and various publishers, has been active in creating and developing educational materials to meet these challenges.

In recent years, a great many consumer electronic products have been introduced and the traditional radio and television receivers have become more complex. As a result, the pressing need for training programs to permit students of various backgrounds and abilities to enter this growing industry has induced EIA to sponsor the preparation of an expanding range of materials. Three branches of study have been developed in two specific formats. The tables list the books in each category; the paragraphs following them explain these materials and suggest how best to use them to achieve the desired results.

The Basic Electricity-Electronics Series

Title	*Author*	*Publisher*
Electricity-Electronics Fundamentals	Zbar/Sloop	McGraw-Hill Book Company
Basic Electricity	Zbar	McGraw-Hill Book Company
Basic Electronics	Zbar/Malvino	McGraw-Hill Book Company

The laboratory text-manuals in the Basic Electricity-Electronics Series provide in-depth, detailed, completely up-to-date technical material by combining a comprehensive discussion of the objectives, theory, and underlying principles with a closely coordinated program of experiments. *Electricity-Electronics Fundamentals* provides an introductory course especially suitable for preparing service technicians; it can also be used for other broad-based courses. *Basic Electricity* and *Basic Electronics* are planned as 270-hour courses, one to follow the other, providing a more thorough background for all levels of technician training. A related instructor's guide is available for each course.

The Radio-Television-Audio Servicing Series

Title	*Author*	*Publisher*
Television Symptom Diagnosis–An Entry into TV Servicing	Tinnel	Howard W. Sams & Co., Inc.
Television Symptom Diagnosis audiovisual materials	Tinnell	Howard W. Sams & Co., Inc.
Television Servicing with Basic Electronics	Sloop	Howard W. Sams & Co., Inc.
Advanced Color Television Servicing	Sloop	Howard W. Sams & Co., Inc.
Audio Servicing–Theory and Practice	Wells	McGraw-Hill Book Company
Audio Servicing–Text-Lab Manual	Wells	McGraw-Hill Book Company
Basic Television: Theory and Servicing	Zbar and Orne	McGraw-Hill Book Company
Cable Television Technology	Deschler	McGraw-Hill Book Company

The Radio-Television-Audio Servicing Series includes materials in two categories: those designed to prepare apprentice technicians to perform in-home servicing and other apprenticeship functions, and those designed to prepare technicians to perform more sophisticated and complicated servicing such as bench-type servicing in the shop.

The two titles in the apprenticeship servicing course are *Television Symptom Diagnosis—An Entry into TV Servicing* (text, student workbook, instructor's guide) and *Television Symptom Diagnosis,* a series of 33 film loops. The first is a set consisting of a well-illustrated text, a student response manual, and an instructor's guide—all designed for people with no previous electronics training—to provide them with job-entry trouble-shooting skills for servicing in the home and shop. The text utilizes the "cue-response" concept of diagnosis, concentrates on identifying abnormal circuit operation and symptom analysis, and develops skills in trouble-shooting. In using the response manual, students are exposed to hundreds of television trouble symptoms through color photos and illustrated problems. The instructor's guide is a complete and essential professional course of study that also contains the answers to questions and problems in the text and lab manual.

Television Symptom Diagnosis consists of a series of color-sound motion picture film loops or slides, a student workbook, and an instructor's guide. These audiovisual materials provide integrated learning systems for color-television adjustment and setup procedures, trouble-symptom diagnosis, and the ability to isolate troubles to a given stage in the receiver, concentrating on the requirements for servicing in the customer's home. But these audiovisual materials can also be used to supplement all levels of television courses. This medium is especially suitable for students who may have reading and, in turn, learning difficulties.

Since only a minimum of electronics theory is presented in the two courses described above, it is expected that apprentices completing these programs will be motivated to progress to more comprehensive programs in order to deepen their understanding of electronics, to really know what makes the radio and television receiver work, and to become proficient in servicing all consumer electronics entertainment items. These in-depth studies are provided in the following materials.

The intermediate *Television Servicing with Basic Electronics* (text, student workbook, instructor's guide) goes beyond the basics and expands on the math and use of test equipment introduced in the beginning text. The book continues the diagnostic troubleshooting method.

Advanced bench-type diagnosis servicing techniques are covered in *Advanced Color Television Servicing* (text, student workbook, instructor's guide). Written primarily for color television servicing courses in schools and in industry, this set follows the logical diagnostic troubleshooting approach consistent with the manufacturers' approach to bench servicing.

Audio Servicing (theory and practice, text-lab manual, and instructor's guide) covers each component of a modern home stereo with an easy-to-follow block diagram and a diagnosis approach consistent with the latest industry techniques.

The bench-type service technician courses consist of *Basic Radio: Theory and Servicing* and *Basic Television: Theory and Servicing.* These books provide a series of experiments, with preparatory theory, designed to provide the in-depth, detailed training necessary to produce skilled radio-television service technicians for both home and bench servicing of all types of radio and television. A related instructor's guide for these books is also available.

The Industrial Electronics Series

Title	*Author*	*Publisher*
Industrial Electronics	Zbar	McGraw-Hill Book Company
Electronic Instruments and Measurements	Zbar	McGraw-Hill Book Company

Basic laboratory courses in industrial control and computer circuits and laboratory standard measuring equipment are provided by the Industrial Electronics Series and their related instructor's guides. *Industrial Electronics* is concerned with the fundamental building blocks in industrial electronics technology, giving the student an understanding of the basic circuits and their applications. *Electronic Instruments and Measurements* fills the need for basic training in the complex field of industrial instrumentation. Prerequisites for both courses are *Basic Electricity* and *Basic Electronics.*

The foreword to the first edition of the EIA-cosponsored basic series states: "The aim of this basic instructional series is to supply schools with a well-integrated, standardized training program, fashioned to produce a technician tailored to industry's needs." This is still the objective of the varied training program that has been developed through joint industry-educator-publisher cooperation.

Peter McCloskey, President
Electronic Industries Association

PREFACE

This textbook, *Cable Television Technology,* is the result of the author's efforts to find appropriate training material for a cable technician training course he teaches at O'Fallon Vocational Technical School. Despite the number of cable systems nationwide, and the increasing technical sophistication of the systems, little has been available until now. *Cable Television Technology* fills the need for this type of text by covering all aspects of cable television (CATV) operation, from the traditional "lineman"-oriented topics to the high-technology subjects that come into play with satellite antennas and fiber-optic links. Since many cable systems incorporate program production facilities, several chapters are devoted to an overview of studio and broadcast technology. Another goal of this text is to prepare the student for the use of electronics manufacturers' service and operating literature, which will always be the primary source of information for the working technician.

The text is organized as follows: Chapter 1 is an overview of CATV—its history, the services it provides, the franchising process, the operational units of a cable system, and CATV job classifications. Chapters 2 and 3 provide an overview of CATV broadcast operations and equipment, and a review of television broadcast electronics.

The study of the technology that is specific to CATV begins in Chap. 4. You will learn about the main distribution point of a cable system, called the *head end* of the system, and you will review the operation of a TV receiver. Chapter 5 covers coaxial cables and their new technological competition, fiber optics. Passive devices such as cable connectors, splitters, and terminators are also covered. Chapter 6 introduces active devices with power supply circuits and standby power supplies. Chapter 7 covers distribution amplifiers and the cable system as a whole. Chapter 8 introduces the measurement of signal levels and the interpretation of cable system maps, and discusses manufacturers' literature. Chapters 9 through 14 cover the construction and maintenance of the cable distribution network—the hand and power tools that are required to install and maintain cable equipment, safe operation of cable and electronics servicing equipment, pole climbing techniques (also with a strong orientation toward safe work practices), and detailed information on the construction of aboveground and belowground distribution systems. Chapters 15 and 16 deal with the subscriber installation, and also include test equipment as well as the connection of FM service, VCRs, and alarm systems. There is also a section on subscriber service troubleshooting.

Each chapter begins with a set of learning objectives, and concludes with a summary and set of review questions. Where appropriate, there are numerical problems for you to work out based on the examples given in the chapter.

At the end of the book you will find appendices that contain sections on map symbols, troubleshooting, test procedures, and more.

The author and publisher wish to acknowledge the assistance and suggestions of the manuscript's reviewers. For the Electronic Industries Association, we wish to thank Christopher F. Fabian of North American Phillips, Emmanuel E. Henry of Matsuchita Engineering and Service Company (MESCO), and Stan Nawrocki of the Milwaukee Area Technical College. We also are grateful for the assistance we received from Steven Johnson and Gary Wallace of Clackamas Community College.

Kenneth Deschler

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I would also like to express my appreciation to my wife Mary for her typing of the manuscript, as well as to my sons Kenny and George and my daughter Mary for their patience and understanding.

SAFETY

Electronics technicians work with electricity, electronic devices, motors, and other rotating machinery. They are often required to use hand and power tools in constructing prototypes of new devices or in setting up experiments. They use test instruments to measure the electrical characteristics of components, devices, and electronic systems. They are involved in any of a dozen different tasks.

These tasks are interesting and challenging, but they may also involve certain hazards if technicians are careless in their work habits. It is therefore essential that the student technicians learn the principles of safety at the very start of their career and that they practice these principles.

Safe work requires a careful and deliberate approach to each task. Before undertaking a job, technicians must understand what to do and how to do it. They must plan the job, setting out on the workbench in a neat and orderly fashion the needed tools, equipment, and instruments. Extraneous items should be removed, and cables should be securely fastened.

When working on or near rotating machinery, loose clothing should be anchored, ties firmly tucked away.

Line (power) voltages should be isolated from ground by means of an isolation transformer. Powerline voltages can kill, so these should *not* come in contact with the hands or body. Line cords should be checked before use. If the insulation on line cords is brittle or cracked, these cords must *not* be used. TO THE STUDENT: Avoid direct contact with any voltage source. Measure voltages with one hand in your pocket. Wear rubber-soled shoes or stand on a rubber mat when working at your experiment bench. Be certain that your hands are dry and that you are not standing on a wet floor when making tests and measurements in a live circuit. Shut off power before connecting test instruments in a live circuit.

Be certain that line cords of power tools and non-isolated equipment use safety plugs (polarized 3-post plugs). Do not defeat the safety feature of these plugs by using ungrounded adapters. Do not defeat any safety device, such as fuse or circuit breaker, by shorting across it or by using a higher amperage fuse than that specified by the manufacturer. Safety devices are intended to protect you and your equipment.

Handle tools properly and with care. Don't indulge in horseplay or play practical jokes in the laboratory. When using power tools, secure your work in a vise or jig. Wear gloves and goggles when required.

Exercise good judgment and common sense and your life in the laboratory will be safe, interesting, and rewarding.

FIRST AID

If an accident should occur, shut off the power immediately. Report the accident at once to your instructor. It may be necessary for you to give emergency care before a physician can come, so you should know the principles of first aid. You can learn the basics by taking a Red Cross first-aid course.

Some first-aid suggestions are set forth here as a simple guide.

Keep the injured person lying down until medical help arrives. Keep the person warm to prevent shock. Do not attempt to give water or other liquids to an unconscious person. Be sure nothing is done to cause further injury. Keep the injured one comfortable until medical help arrives.

ARTIFICIAL RESPIRATION

Severe electric shock may cause someone to stop breathing. Be prepared to start artificial respiration at once if breathing has stopped. The two recommended techniques are:

1. Mouth-to-mouth breathing, considered more effective.
2. Schaeffer method

These techniques are described in first-aid books. You should master one or the other so that if the need arises you will be able to save a life by applying artificial respiration.

These safety instructions should not frighten you but should make you aware that there are hazards in the work of an electronics technician—as there are hazards in every job. Therefore you must exercise common sense and good judgment, and maintain safe work habits in this, as in every other job.

1
CHAPTER
AN OVERVIEW OF CABLE TELEVISION

INTRODUCTION

In this chapter you will learn about:

1. The background of cable TV
2. Cable system components and variations
3. Problems and legal requirements
4. Cable system marketing and employment opportunities
5. Alternatives to CATV

What began in 1947 as a solution to poor television (TV) reception has now become a $6 billion/year industry. Cable television (CATV) has changed the TV viewing habits of millions and now provides employment and economic growth that were nonexistent 40 years previously. The credit for the success of CATV is due to those individuals who had the foresight to realize that this nation had an appetite for more TV programming than the commercial TV stations were able to furnish.

By September 1985, with almost 1500 TV stations in operation, there were approximately 85 million households with one TV set (90 percent in color), and of that number, 49 million had two or more TV sets. The average amount of TV viewing was 50 hours (h) per week, and the majority of the viewers were women.

At present almost 50 percent of the households with a TV receiver subscribe to cable service, and of these, more than 50 percent pay for Premium services. This means that over 40 million homes currently receive 12 to over 30 channels of TV programming each.

HISTORY

In 1947, the vast majority of TV sets in use in this country were located in homes in or near the metropolitan areas of New York, Chicago, and Los Angeles. Unfortunately, most of the U.S. population lived too far from these metropolitan areas for satisfactory TV reception.

Cable TV was developed in the late 1940s and early 1950s as a solution to this problem of poor TV reception in rural and mountainous areas of the country. Because commercial TV station signals are transmitted at very high frequencies and travel in straight paths, they are easily reflected by tall buildings and mountains. To obtain stronger and clearer signals, people living in these areas (Fig. 1-1) were forced to install receiving antennas either on their roofs (Fig. 1-2) or mounted on tall towers (Fig. 1-3). But even these measures were not always satisfactory.

It was well known at the time that anyone who could mount the antenna at a sufficient height and who lived within broadcasting range of a TV station could receive acceptable signals. However, the cost of such an installation for the average homeowner was prohibitive.

The first CATV systems were implemented in Mahanoy City and Lansford, Pennsylvania. Mahanoy City is located approximately 80 miles (mi) northwest of Philadelphia in a valley surrounded by the Appalachian Mountains. In Mahanoy City, Mr. John Walson, a local businessman, was having trouble selling TV sets because of the poor quality of signals received from television stations in Philadelphia. He had installed an antenna on the roof of his store, but to no avail. In desperation, he erected an antenna on a nearby hill and drove prospective TV purchasers up to the antenna for demonstrations. Obviously the answer was to bring the signal to the customer, and not the customer to the signal. With this in mind, he bought some surplus wire and strung it on local power company poles. He then connected one end of the wire to his antenna and the other to sets in his store window. Soon people gathered around the sets in amazement. Some even agreed to purchase sets on the condition that Walson connect them to his antenna. As time passed, more TV sets were connected to this master antenna. In 1949, Walson replaced the flat twin-lead antenna wire with coaxial cable. In 1952, he obtained permission from two New York stations to use their signals, thus providing the subscribers in Mahanoy City with even more channels to choose from.

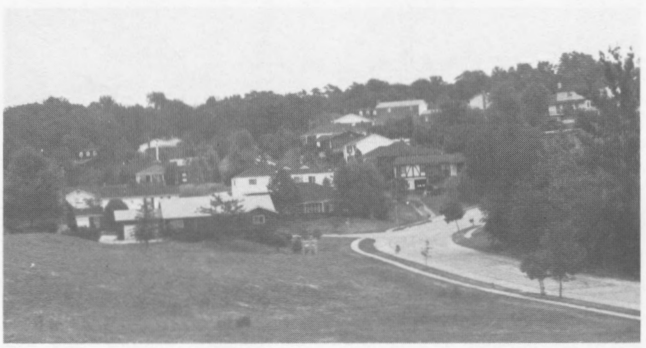

Fig. 1-1. Poor signal area.

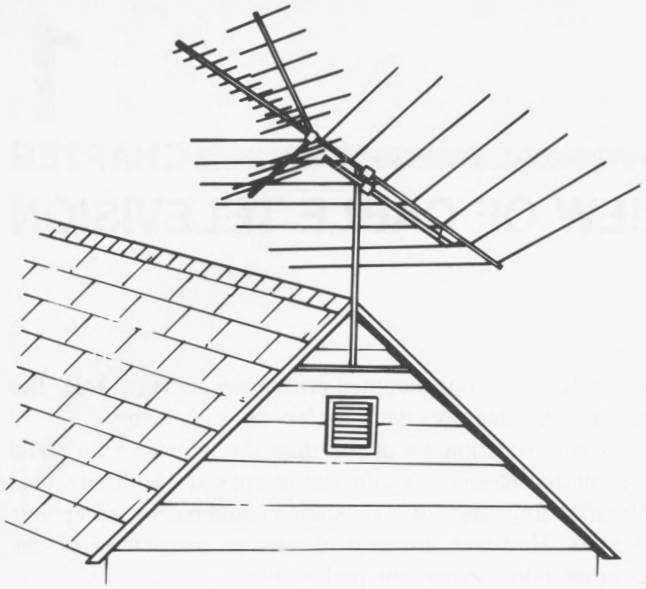

Fig. 1-2. High gain antenna mounted on roof.

At about the same time, a group of citizens in Lansford, Pennsylvania formed the Panther Valley Television Company. They installed a master antenna on a nearby hill and brought its signals into town. Both the Panther Valley system and Mr. Walson share the distinction of providing the first cable systems in the United States.

In 1948, almost 3000 mi away, in Astoria, Oregon, Mr. Ed Parsons was involved in efforts to receive TV signals from Seattle, Washington. After much experimentation, he found that the best signal could be obtained from a nearby hotel. With the permission of the hotel owners, Mr. Parsons installed an antenna. Soon everyone wanted to be hooked up to that antenna.

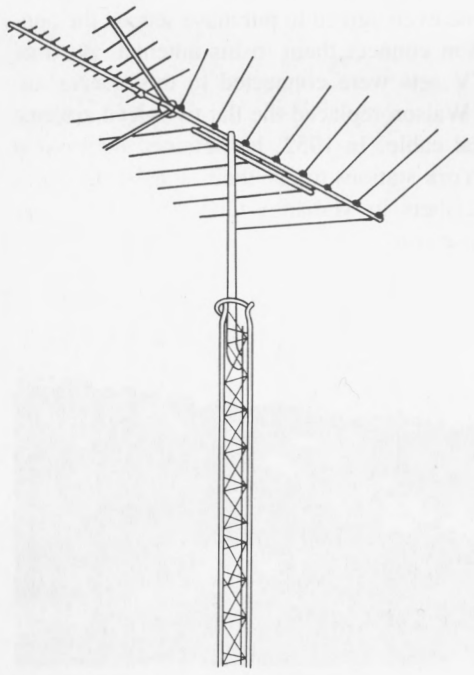

Fig. 1-3. Antenna mounted on tower.

By 1952, cable systems served over 14,000 households in more than 70 communities. By 1961, there were over 700 CATV systems in the United States. By 1971, over five million homes were receiving CATV service from almost 2600 systems.

When the acronym "CATV" was first used, it stood for *c*ommunity *a*ntenna *tele*vision, but because of the use of coaxial cable, it has now been changed to *ca*ble *tele*vision.

The early cable operators were mostly small businesspeople or engineers, thus making the industry at that time a collection of small "mom and pop" systems. As the popularity of CATV increased, some of the smaller systems consolidated and formed multiple systems operations (MSOs).

As the CATV industry grew, an increasing number of people realized that good TV reception could be obtained without the expense of owning and maintaining their own antenna system.

PARTS OF A CABLE SYSTEM

The main parts of a cable system (Fig. 1-4) include:

1. *The signal origination sites*—the outside sources used by CATV systems to provide their subscribers with programming. Signal origination sites include satellite programming stations, microwave relay stations, commercial TV stations, and commercial FM radio stations.
2. *The antenna site*—the area where all the antennas used to receive the programming from the signal origination sites are located. Figures 1-5 and 1-6 show various antennas at a CATV antenna site. The four basic types of antennas that might be found at a typical antenna site location are those designed to receive microwave transmissions, signals from all the local TV stations, signals from FM radio stations, and satellite signals. Antennas used to receive satellite signals are referred to as *Television receive-only* (TVRO) antennas.
3. *The head-end*—the nerve center for the entire CATV system. It is here that the signals from the antennas as well as any locally produced [local-origination (LO)] signals are processed, combined, and assigned a channel on the cable. Figure 1-7 shows the signal processing equipment of a typical head-end.
4. *The distribution system*—used to distribute the signals from the head-end to the subscribers. The distribution system is made up of coaxial cable and other devices that are placed either on poles (aerial construction) or buried in trenches (underground construction). Figures 1-8 and 1-9 show both aerial and underground cable installations. Periodically the signals must be reamplified to overcome the losses within the cable itself.

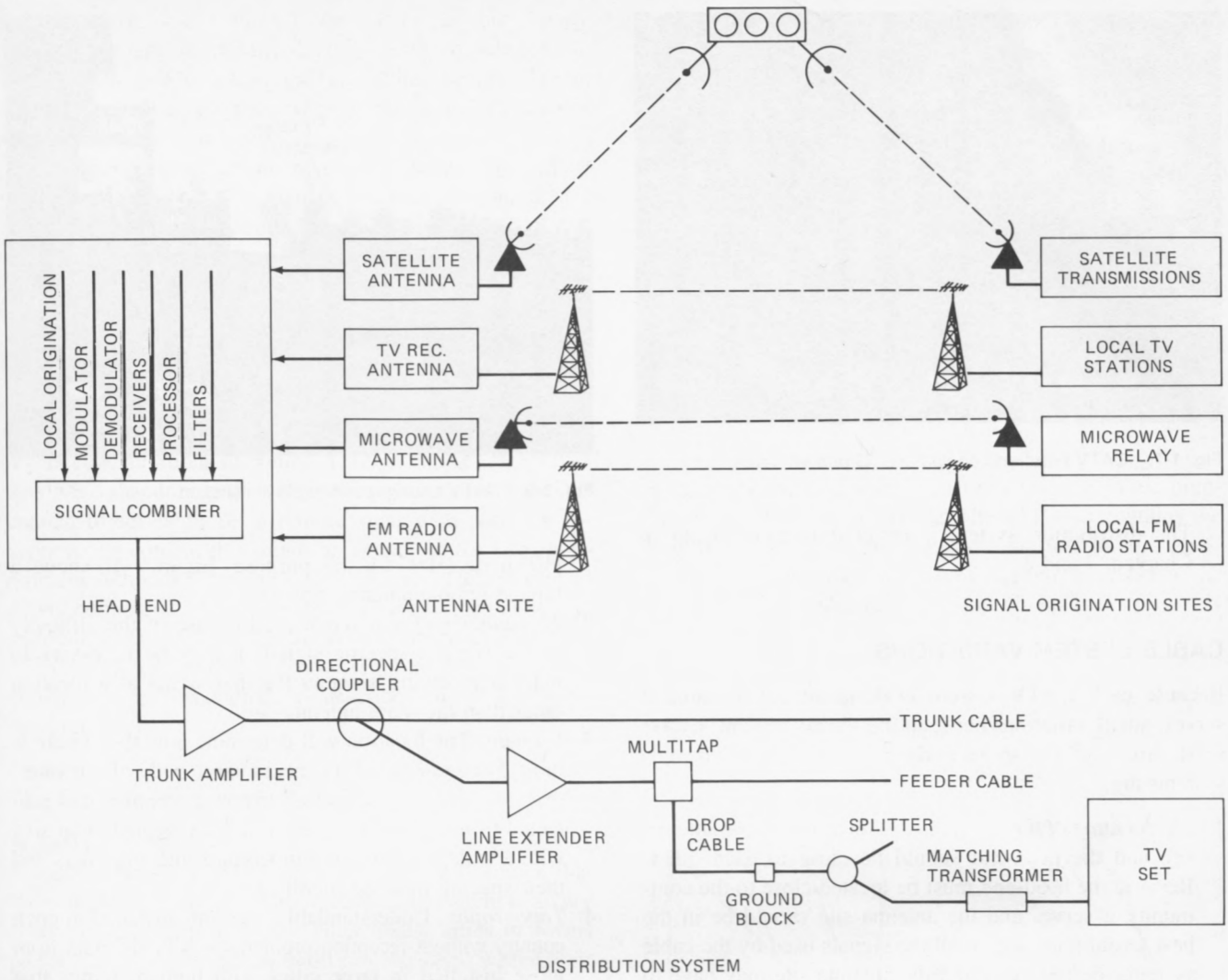

Fig. 1-4. Parts of a cable television system.

Fig. 1-5. Local radio, television, and microwave antennas at a CATV antenna site. (*Cencom Cable Television*)

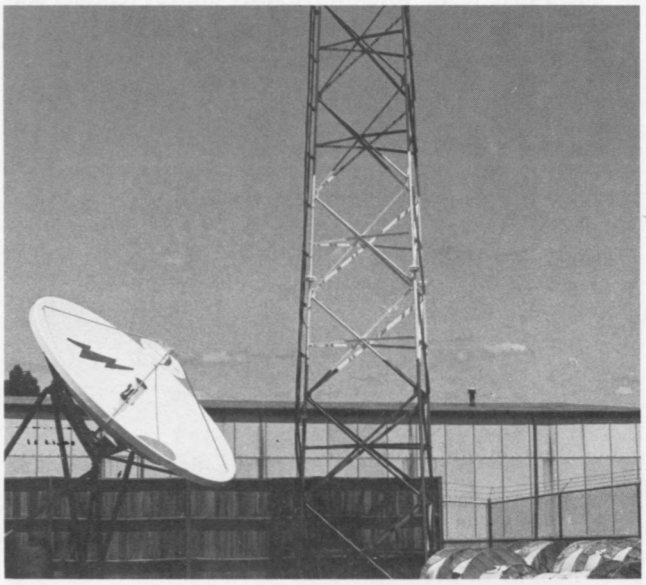

Fig. 1-6. Satellite receiving antenna at a CATV antenna site. (*Cencom Cable Television*)

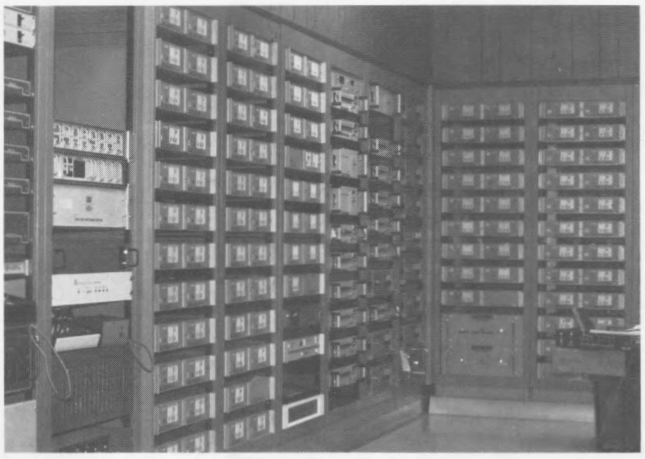

Fig. 1-7. CATV head-end equipment. (*Group W Cable*)

The distribution system is covered in more detail in Chapters 7 and 8.

CABLE SYSTEM VARIATIONS

Because each CATV system is designed for the area it serves, small variations between individual systems always exist. Some of the more noticeable differences between systems are:

1. *The location of the antenna site*. Ideally both the antenna site and the head-end should be close to each other. Because the head-end must be located close to the community it serves and the antenna site should be in the best location to receive all the signals used by the cable system, the head-end and the antenna site may have to be located miles apart. The signals then must be sent to the head-end by cable or, if the distance is great, by microwave relay. Microwave relay utilizes repeater stations to receive and retransmit highly directional radio beams. The CATV relay services (CARS) has been assigned frequencies between 12.7 and 13.2 gigahertz (GHz) [10^9 hertz (Hz)] for this purpose. Figure 1-10 shows a typical remote antenna site.
2. *The number of antenna sites*. Because of the difficulty of receiving a specific signal, it may be necessary to place a receiving antenna for that signal at a location other than the main antenna site.
3. *Climate*. The location will determine how the system is built. For example, if it is near a large body of saltwater, special cable is used and all exposed equipment is protected from corrosion. If the system is located in an area with a wide variation of temperature, the amplifiers and their spacing must be modified.
4. *Topography*. Understandably, systems installed in open country without reception problems will be different from those installed in large cities with high buildings that hinder good signal reception.
5. *Multiple-hub construction*. When a cable system is located in an area spread out over many miles, it is sometimes necessary to install more than one head-end. When multiple head-ends are needed, one acts as the master while the others act as slaves. Usually a large cable known as a "supertrunk" is used to connect the various hubs. An example of multiple-hub construction is shown in Fig. 1-11. As you can see, none of the trunk cables exceeds 5 mi in length.
6. *Amount and type of head-end equipment*. Depending on the requirements of the system, the number and types of receivers, processors, modulators, and demodulators needed will vary.

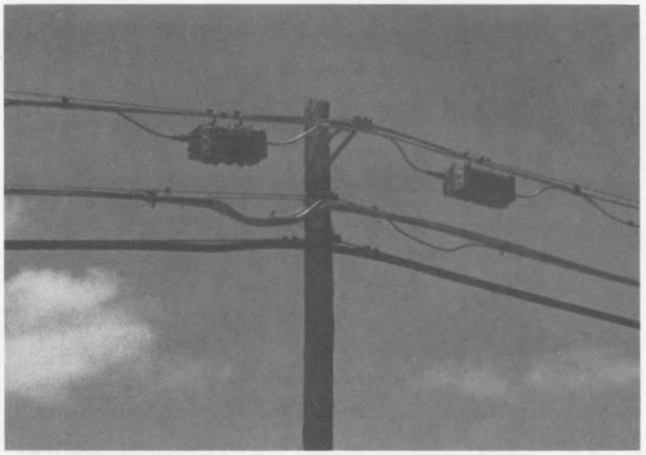

Fig. 1-8. Aerial cable and amplifiers.

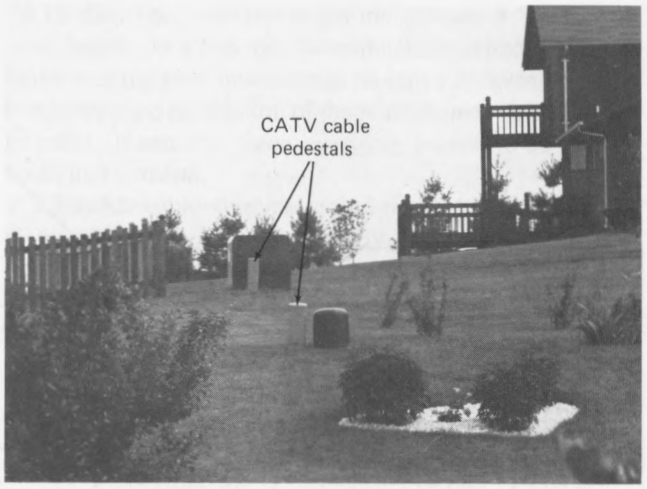

Fig. 1-9. CATV underground cable installation.

LEGAL CONSTRAINTS AND OTHER PROBLEMS ENCOUNTERED IN GROWTH OF THE CATV INDUSTRY

As the number of cable systems increased, so did the problems. When CATV systems first began stringing TV wires, they agreed to pay the owners of the poles a small fee for each pole used. But soon the owners of the poles realized

that they were in a position to ask for more money. This resulted in many court battles, state-mandated pole attachment rates and regulations, and federal intervention. Eventually, pole attachment rates were agreed on and the growth of cable systems continued.

In addition, some commercial TV stations objected to the importation of CATV signals into their viewing areas. They felt that their revenues would suffer because of the competition within their market. However, they soon realized that with an increase in programming, people were spending more time watching TV. Because of this increase in viewership and the expanding TV market, they found that they could charge more for their advertising time.

Because of the high cost of installing and maintaining a cable system, CATV systems generally were installed near higher concentrations of homes. This, of course, meant that they were abandoning the very people whom they had been created to serve, those in remote areas with poor TV reception. To combat this trend, an agency of the U.S. government authorized low-interest loans to local telephone and power companies. These companies were to then build and maintain CATV systems in the rural community.

Cable TV companies are now required to obtain franchises prior to installation, as described in the following paragraphs.

The Franchise Process

A franchise is a right granted to a company to market its services within a given community. It is well known that the construction and installation of a cable system is a very costly and complex process. Thus, many cities or towns prefer that cable companies build cable systems within their boundaries and share the profits with them. Franchises may be either exclusive (granted to one franchise holder) or nonexclusive (granted to more than one franchise holder). In the majority of cases, although a nonexclusive franchise is granted, only one company is awarded the franchise.

Once an exclusive franchise is granted, no other company can build a system in the community for the duration of the franchise period. Most franchises are granted for 15 years and are renewable every 5 years thereafter.

To begin the process, an advisory committee made up of representatives from the community should be established. The primary issues that this committee addresses are (1) who will oversee the evaluation of bidders for the franchise, (2) the term of the franchise, (3) the requirements for renewal of the franchise, (4) the amount of the application fee, (5) the expiration date for applications, and (6) whether the franchise should be exclusive or nonexclusive.

After the committee has determined the requirements, procedures, and specifications of the cable system, an ordinance is passed reflecting these points.

Once the ordinance is written, a set of forms known as a *request for proposal* (RFP) is given to the applicants. The purpose of the RFP is to determine which applicants are able to provide cable service to the community. The RFP contains information and instructions relating to the preparation and filing of proposals. The RFP also contains the conditions and provisions regarding the installation, operation, and maintenance of a CATV system. In addition, the procedure to be used in evaluating applicant proposals is outlined.

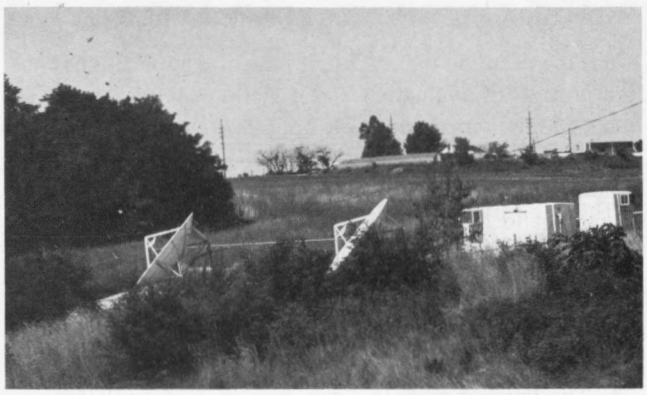

Fig. 1-10. Remote CATV antenna site.

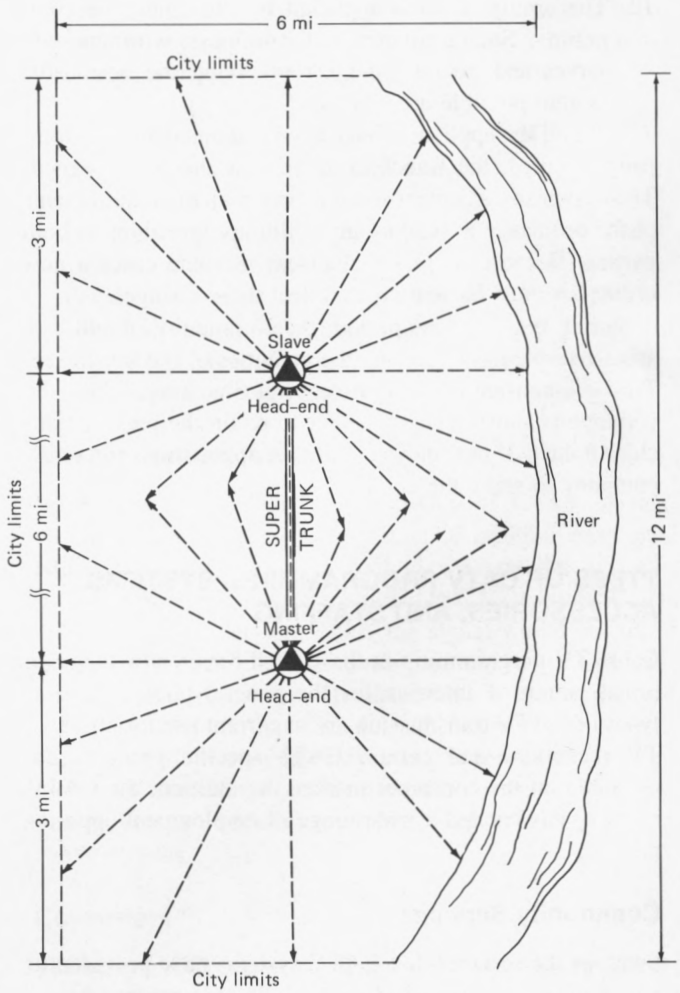

Fig. 1-11. Typical CATV hub construction.

Evaluation and Selection of a Franchisee

Once the deadline for accepting franchise applications ends, the process of evaluation and selection should begin. The most common method of selecting the company is to assign either points or weights to a list of qualifications. These qualifications should be ones that the community feels are important to them. Some of the more common qualifications that communities feel are important in the choice of an applicant are:

1. The amount of experience that each bidder has in cable system operation.
2. The level of technical expertise of each applicant.
3. The ability to complete the construction on schedule.
4. The amount and types of local origination programming being offered.
5. The number of public service and access channels being offered.
6. The tier structure of the proposed system.
7. The subscriber rate structure.
8. The labor practices of an applicant in terms of minority and handicapped hiring and past union management relationships.
9. The financial structure of each applicant.
10. The ability of each applicant to "fit" into the community. Such attributes as friendliness, willingness to serve, and genuine interest in giving the best cable system possible are evaluated.

After all the applicants have been evaluated and the company selected, the franchise agreement should be signed. The franchise agreement should contain all the requirements of the ordinance as well as any additions agreed on by both parties. Because of major changes, in some cases a new ordinance must be written to reflect these changes.

During the franchise period, the community should take an active role in monitoring the activities of the franchisee. This is important because as renewal time approaches, the community must decide whether to retain the present franchise holder. If not, they should take applications for a new company to serve the community.

TYPES OF CATV PROGRAMMING, SYSTEMS, ACCESSORIES, AND STAFFING

Cable TV programming in the United States now covers a broad gamut of interests for the general public. Several types of CATV transmission are in current use for effective TV reception, and certain CATV-specific products are available on the consumer market. In addition, the CATV industry has created a wide range of employment opportunities.

Community Services

Some of the services that CATV systems have provided to communities are described in the following paragraphs.

Local News Coverage

Because the commercial TV networks limit their news coverage to such short periods, they are really only a headline service. Cable TV, on the other hand, can devote entire channels to the news. Because many neighborhoods are too small to be covered by the large TV stations, the local cable company can be of service by covering their news and sporting events.

Public Access To Cable Channels

In some cable systems, cable channels are set aside for the public to express their opinions on almost any subject. They also provide studio facilities (and, in some cases, training in production methods) to religious, ethnic, and minority groups who wish to produce programs aimed at smaller segments of their communities. Unfortunately, many cable companies feel that the infrequent use of these channels hardly justifies the expense needed to maintain them.

Educational Programming

Local educational institutions may have an entire cable channel devoted to their use. The channel is used to conduct classes, offer seminars, or provide basic educational programs aimed at the foreign-born.

Local Government

Local politicians can obtain time to present issues that would not be of interest to a broader range of viewers. Also, many systems cover their city council meetings on a regular basis.

Basic versus Premium Programming

The two different types of programming found in CATV systems are known as *Basic* and *Premium*. Except for a few CATV systems, everyone who subscribes to CATV must take the Basic package of programming. Any programming other than Basic is known as Premium programming.

Basic Programming

The types of programming included in the Basic package are (1) all the local TV stations; (2) superstations such as WGN in Chicago or WTBS in Atlanta; (3) distant stations received through microwave transmissions; (4) satellite broadcasting such as news, religious programming, sports, financial reports, government debates and reports, children's programs, higher-education programming, foreign-language programs, cultural programming, and health and nutrition programming; (5) automated services such as program listings for the day, local employment opportunities listings, weather radar scan, classified advertisements, real estate offerings, community calendars, time and weather information, and election results; and (6) FM background music for automated services.

Premium Programming

Premium programming is programming for which subscribers pay extra. Various methods are employed to prevent subscribers who only pay for the Basic package of programming from receiving the Premium channels. Two of the more common methods are to either distort the picture and sound (called "scrambling") or to eliminate the signal through the use of a device known as a "trap." The trap is inserted in the cable entering the subscriber's home and eliminates (traps out) signals from the Premium channels. Premium channels constitute one tier (level) of programming. For example, a system that offers three Premium channels is a four-tier system (Basic channels plus three Premium channels). Some types of Premium programming are:

1. *Movies and specials*. Premium channels such as Home Box Office (HBO), Showtime (SHO), and The Movie Channel (TMC) are popular among CATV subscribers for this type of programming. Some CATV systems allow the attachment of an FM radio to the cable to allow subscribers to listen to Premium programming in simulated stereo.
2. *Music and music-oriented programming*. Popular channels are the Nashville Network and Music TV (MTV). Some systems may include one or more of these channels as part of their Basic programming package.
3. *Arcade-type games*. Subscribers who choose this service are given the option of many games each month to choose from. They must have a game panel on which they ask for the current listing of games. Once they choose the game, it is stored in the memory of the panel, where it remains until the player tires of it and turns off the console or chooses another game.
4. *Pay per view*. This option is available for special sporting events or theatrical performances that would not normally be shown by either commercial or regular cable TV stations. On paying the fee, the subscriber is given a device to remove the scrambling signal, shown how to install it, and told which cable channel will be carrying the special. When the subscriber returns the unscrambling device, the deposit is returned. To ensure that the device is not used again, the pay per view channels are rotated. In an addressable system (where the cable company can direct signals to a specific home) the subscriber simply has to notify the cable company in order to receive the special program. These specials generally run from 3 to 4 h in length.

Two-Way Cable Services

Two-way transmission capability was added to CATV in the 1970s. Instead of merely receiving information, the subscriber is now able to respond. A hand-held unit allows the subscriber to interact with the programming by answering questions posed by a studio moderator. At the cable company a computer scans each subscriber and records the responses. This information is tallied, and the results are either given on the screen or mailed to those who request it. Some other uses of two-way cable are now or could potentially be:

1. To provide home security by connecting fire or burglar alarm sensors to the cable. In this setup, the home is monitored several times each minute by the computer. If a fire or break-in occurs, the local police or fire department is notified immediately.
2. To contact medical facilities when either a "panic button" or a small transmitter is activated.
3. To provide utilities with the amount of gas, electricity, or water that the subscriber has used, thus eliminating the need for monthly meter readings.
4. To provide energy management of the home. The cable company computer controls the furnace or the air conditioner. During periods of absence the computer maintains the home at an energy-efficient temperature. When the home is to be reoccupied, the computer will return the temperature to its former level.
5. To retrieve information. Through the use of a terminal (computer keyboard and screen) the subscriber can access a database for information. A database is a body of facts pertaining to one or more related subjects contained in the computer memory. This feature is especially valuable to students.
6. To transmit mail electronically. This is accomplished through the use of an addressable device in the home along with a printer. The mail or other correspondence is routed to the proper home through data signals. These signals can either turn on the printer, activate a signal device, or present the information on the TV screen. The information may also go to a storage device to be sent to the screen or printer at a later time. Newspapers and magazines could also be transmitted this way.

Satellite Retransmission

During the mid 1970s, retransmission of CATV signals became a reality through utilization of orbiting earth satellites. Basically, signals are sent up to the satellite by earth stations, received, and retransmitted to CATV systems subscribing to their service. Thus, the signal would not have to be sent through microwave relay stations to systems separated by great distances. The disadvantage to relaying microwave signals is that each time the signal is amplified, the quality of the signal decreases. Superstations are regional TV stations that transmit signals not only to the area that they serve, but also to satellites for retransmission to cable systems.

Converters

The early CATV systems offered only two or three channels. With the addition of locally originated programs and

distant stations, soon all 12 channels (Channels 2 to 13) were filled. With the availability of additional programming from satellites in the 1970s, the method of delivering signals in CATV systems had to be changed. The method decided on by CATV companies was to install a converter between the cable and the subscriber's set. The converter accepts all the signals sent out on the cable and converts or changes them to one channel (generally Channel 3). In this way the subscriber changes channels on the hand unit and leaves the TV channel selector in one position. Some systems today offer as many as 108 channels to their subscribers. At this point, however, they would be hard pressed to fill them with programming.

Cable-Ready TV Receivers

Some people are now purchasing "cable-ready" TV sets only to find that they still need a converter from the cable system. The reason for this is that the Premium channels must be unscrambled and the circuitry for this is contained within the converter unit. Also, if the TV set is equipped with remote control, it cannot be used because the station selector must remain set on Channel 3 for proper converter functioning.

Employment in the CATV Industry

The major job classifications in the CATV industry are described in the following paragraphs. Understandably, a *small* system would not utilize all of these people; therefore, duties are shared. In a large system, it is more likely that each person would have a specific job description and would not share in the duties of other employees.

Administration

District Manager. This individual is responsible for the overall management of a group of cable systems owned by a multiple systems operation (MSO).

Systems Manager. This person is responsible for the overall management of an individual cable system.

Sales Manager. This person oversees all salespeople, works with the local customer service representatives, and develops ideas for sale promotions.

Marketing Director. This individual's job is to sell CATV services to the community by market research, advertisement, campaigns, and public speaking engagements.

Office Manager. The office manager supervises the customer service representatives, handles billing problems, and is concerned with the number of subscribers in the system, the average subscriber rates, equal employment opportunities, and personnel recruitment.

Local Origination (LO) Manager. This person manages all aspects of local origination, public service, and specialty programming performed in the studio of a local cable system.

NOTE: Usually the positions of sales manager and the marketing director are combined, or the marketing director is at the district or regional level.

Sales

Advertising Salespeople. These employees sell advertising time on cable network shows to local merchants.

Cable Service Salespeople. These individuals sell cable service door to door in areas recently franchised for cable service. They may also be called on for remarketing if subscriber levels are low in a particular area.

Clerical

Accountant or Bookkeeper. This individual maintains the books, prepares tax forms, and oversees the financial condition of the company.

Clerk. This person handles accounts payable and receivable, customer billing and delinquent accounts, purchase orders, and payroll.

Customer Service Representative. The service representative handles customer complaints, orders for service hookups and disconnects, and any other matter that customers wish to discuss.

Technical

Chief Engineer-Technician. This individual is an electronic technician with experience in maintaining, adjusting, and repairing the head-ends receiving, processing, and signal distribution equipment. The chief engineer-technician also supervises all the technical personnel. The duties of this position include professional training of the technical staff, making design changes and other modifications within the cable system, and advising management personnel on franchise application form preparation.

Installation Supervisor. This supervisor trains installers and monitors the quality of their work.

Bench Technician. This is an electronics technician whose responsibilities include the diagnosis and repair of malfunctioning equipment and the alignment of amplifiers and head-end equipment, as well as the repair of the studio equipment if the system is so equipped.

Plant Maintenance-Trunk Service Technician. This worker is responsible for repairing damaged coaxial cable, making service calls for loss of signal or poor-quality signals, testing and troubleshooting of the distribution system, transferring cable from one pole to another, and installing amplifiers and other devices on the coaxial cable.

Installer. This individual installs coaxial cable from the cable distribution system into the subscribers' homes and connects it to their TV sets.

Converter Repair Person. This technician prepares con-

verters for issuance to customers. Preparations include cleaning, aligning, minor repairs, and packaging.

Warehouse Person. This employee is responsible for inventory control.

Dispatcher. The dispatcher receives the trouble calls and assigns technicians to remedy the problem and also coordinates hookups and disconnects.

Studio

This category is covered in more detail in the next chapter. The following job titles are associated with the operation of a large studio (in a small studio these jobs are shared):

- Programming director
- Assistant director
- Video technician
- Audio technician
- Floor manager
- Lighting technician
- Producer
- Makeup technician
- Prop (property) person
- Announcer
- Writer
- Tape librarian

Other Personnel

Purchasing Agent. This person is responsible for purchasing (generally at the regional level) equipment and supplies for all the cable systems owned by the MSO. Additional duties of the purchasing agent include inspection of a system while under construction if this is not performed by the construction project manager, quality control of the products purchased, and keeping abreast of the rapidly changing technology in order to purchase the latest products.

Marketing Analyst-Researcher. This individual determines the type of programming that will be popular in the community being served. This position is usually at the corporate level and utilizes input from the local system.

Construction Project Manager. The construction project manager ensures that all phases of the construction of CATV systems are performed correctly, and on time.

ALTERNATIVES TO CATV

Home Satellite Receivers

Because of the large amount of satellite programs available, many people have invested in home satellite receiving equipment. Between 250,000 and 300,000 Americans, mostly those in rural areas or areas not wired for CATV, own home satellite receivers (earth stations). For an initial investment of less than $2000 an individual can receive over 100 channels of programming. By simply positioning a 6- to 8-ft antenna (''dish'') and tuning a receiver, they can literally have the world at their doorsteps. The frequency band used for home satellite receiver systems extends from 3.7 GHz (3,700,000,000 Hz) to 4.2 GHz (4,200,000,000 Hz).

Direct-Broadcast Satellite

Direct-broadcast satellite (DBS) signal distribution is a new way of supplying additional channels to subscribers not receiving CATV service but able to receive commercial TV stations. This type of distribution is similar in principle to that of the home satellite receiver, except that its signals are scrambled and a fee is charged. Another difference is the frequencies used; DBS systems use frequencies of 11.7 to 12.7 GHz.

Direct-broadcast-satellite systems generally carry five channels of programming such as (1) movies; (2) sporting events; (3) children's programs; (4) news; and (5) special programs, including concerts, soap operas, and variety shows.

Because a higher frequency band is used and the power of the satellite is greater, the receiving antennas used in DBS are smaller than those used in CATV. Dishes ranging from 2.0 to 6.0 ft are able to receive sufficient signals to present clear pictures on a TV screen.

Both the Canadians and the Japanese are presently using DBS systems to bring programming to remote areas in their countries.

SUMMARY

1. The reception of commercial TV in the early years was either poor or nonexistent in mountainous areas of the United States.
2. Enterprising individuals were involved in improving TV reception in those early years through the use of master antenna systems.
3. For expansion beyond a 12-channel system, a device known as a *converter* is used between the cable and the TV receiver. Some converters are used to program Premium services, while others are addressable from the head-end.
4. Cable TV has brought to the community new job opportunities, more news, public access to cable channels, and governmental programming.
5. Because cable systems were not being constructed in areas with small populations, local telephone and power companies built the cable systems. These companies received low-interest government loans.
6. When satellite retransmission began in the mid-1970s, large amounts of programming became available to CATV subscribers.
7. Because of differences in community needs and geographic location, no two systems are built or operated the same.
8. To ensure that a community receives the kind of cable

system that it wants, a CATV ordinance is passed which accommodates the interests of the majority of the community members.

9. A request for proposal (RFP) is an instrument used by a community to ensure that it receives what its members want in cable service.
10. A successful cable system is supported by the expertise and skills of many talented employees in management, sales, production, and technical areas. Success is realized when a system delivers quality pictures, provides good service, and is able to make a reasonable profit.

REVIEW QUESTIONS

1. In 50 words or more, describe a typical CATV system.
2. What do the letters CATV stand for today?
3. What is an MSO?
4. Generally, what channel is tuned on the subscriber's TV set when a converter is used?
5. Explain what a tier is in CATV.
6. What is Basic service? Give three examples of programming found in this type of service.
7. What is Premium service? Give three examples of programming found on Premium channels.
8. Name five services that are now or soon will be available on two-way cable systems.
9. Name the major parts of a modern cable system.
10. In what ways may a cable system vary?
11. Define a franchise.
12 Name three questions that a cable advisory committee should address itself to when writing a cable TV ordinance.
13. What does a typical CATV RFP contain?
14. Name five qualifications that a community should look for when choosing an applicant for a CATV franchise.
15. Name five technical employees of a CATV system.

2
CHAPTER
THE SIGNAL ORIGINATION SITE

INTRODUCTION

In this chapter you will learn about:

1. Studios and studio lighting
2. Graphics
3. Auxiliary rooms and control rooms
4. Microphones
5. TV cameras and viewfinders
6. The CATV satellite system

The source of a CATV program may be a local commercial TV station, a distant commercial TV station whose signal is received through microwave transmission, or a program received by satellite from a Premium channel such as HBO or one of the superstations. Collectively, these sources are known as *signal origination sites*. In addition, any programming done by the CATV system itself makes it a signal origination site as well.

The parts of a signal origination site include studios for program production, auxiliary rooms, the control room, and the transmitter and antenna system. (The transmitter and antenna systems of the signal origination site are discussed in Chapter 3.)

THE STUDIO

The large room shown in Fig. 2-1 is a *studio*. A studio of this size is used for televising major programs such as audience-participation shows.

Smaller studios are used for specialty programs such as news reporting, cooking programs, and person-to-person interviews. The typical studio would contain TV cameras, microphones, portable lighting units, props, and either partitions or curtains. A curtain used as a backdrop is shown in Fig. 2-2. The ceilings are 12 to 14 ft. high to accommodate the lighting fixtures needed to illuminate the televised area. The walls and doorways are soundproofed to prevent noise from entering the studio while programming is under way. The floors are constructed hard and smooth to enable equipment to be moved quietly and prevent wobbling of TV cameras.

The walls and partitions are painted a soft color such as light blue to provide a neutral background. Because of the heat generated by the lights and other electrical equipment, an air conditioning system is needed. The air-conditioning and heating systems must be both efficient and quiet. Generally an intercommunication system is installed between the studio and the control room to enable the director to converse with the people in the studio.

Most commercial TV stations have at least two studios, one for live telecasting and another for taping. A program is taped so that it may be aired at a future date. Most studios used for CATV local origination, on the other hand, are very small and limited in use.

Studio Lighting

Proper lighting of the televised area is an absolute necessity. This is because the TV camera needs light to "see" the scene. The function of the camera is to take light energy and convert it to electrical energy.

The lighting fixtures shown in Fig. 2-3 are attached to a framework called a *grid*. A grid (Fig. 2-4) is a series of

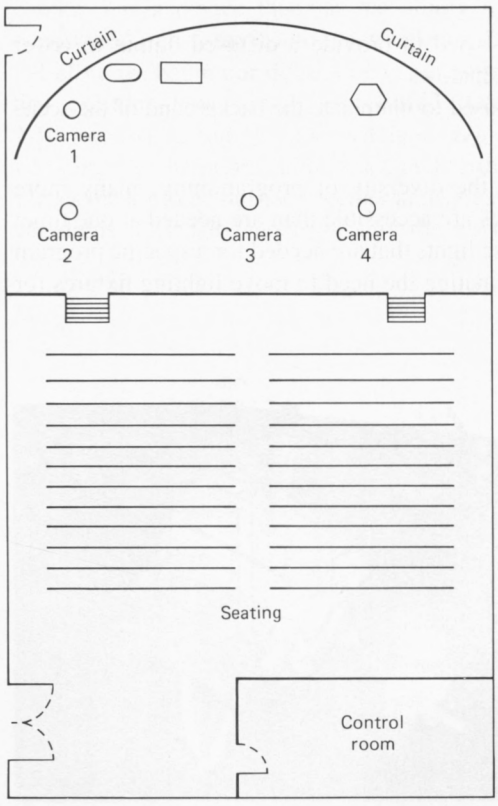

Fig. 2-1. A typical studio layout.

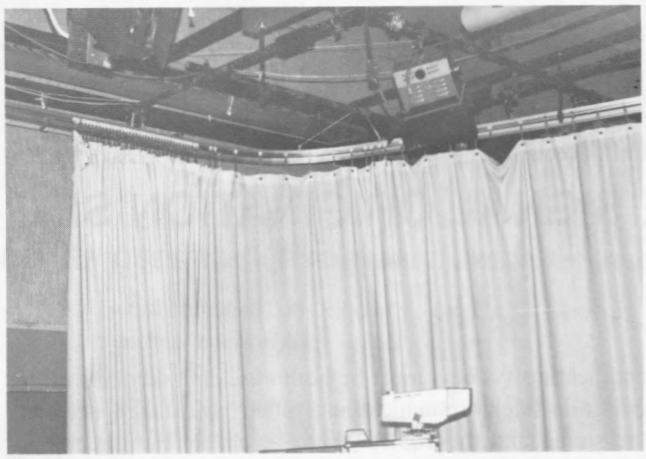

Fig. 2-2. A studio backdrop curtain. (*KETC—St. Louis. Mo.*)

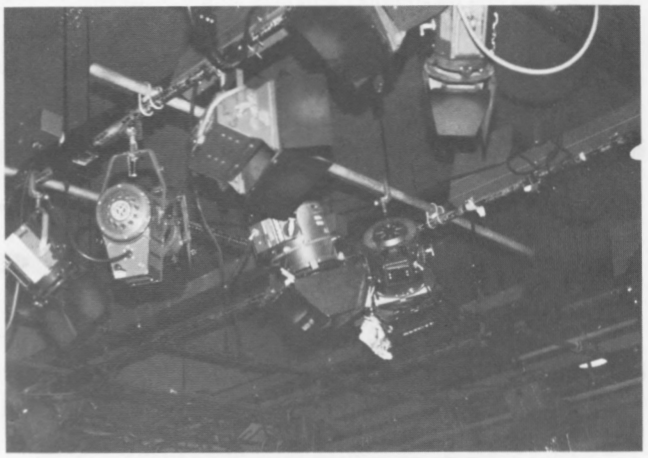

Fig. 2-4. Lighting fixtures on a grid structure. (*KETC—St. Louis. Mo.*)

channels which allow the light fixtures to be moved to different positions. Depending on the need for additional lighting, light fixtures are also mounted on movable stands. The ceiling of the studio is usually painted black to avoid reflections from the lighting units.

Figure 2-5 shows how lights are positioned to best accentuate the object or person being televised. The types and arrangement of these lights are as follows:

1. *Backlights*—separate the subject from the background and give the illusion of depth
2. *Key lights*—provide the main source of illumination on the subject
3. *Fill lights*—used to provide a diffused output to cover and blend shadows
4. *Set lights*—used to illuminate the background of the scene being televised

Because of the diversity of programming, many more lighting fixtures are accessible than are needed at one time; thus, only those lights that are needed for a specific program are used, eliminating the need to move lighting fixtures for each show.

Fig. 2-3. A studio lighting fixture. (*KETC—St. Louis. Mo.*)

GRAPHICS

Graphics are the drawings, photographs, or pictures of various subjects or scenes used in a studio production. An example of the use of graphics would be the photographs and pictures seen behind a newscaster. Other examples of graphics would be a diagram used by a commentator, or the superimposition of a name beneath a person.

Some of the qualities of effective graphics are simplicity of design, lettering size and shape, coloration, and—most important—visual appeal. Although some graphics are produced within the station, most are done by outside sources.

AUXILIARY ROOMS

Besides the studio, many areas contribute to the success of a TV program. Some of these areas are the:

1. *Prop storage area*—should be located close to the studio and is used to store the props and sets needed for various programs. Also contained within the prop storage area

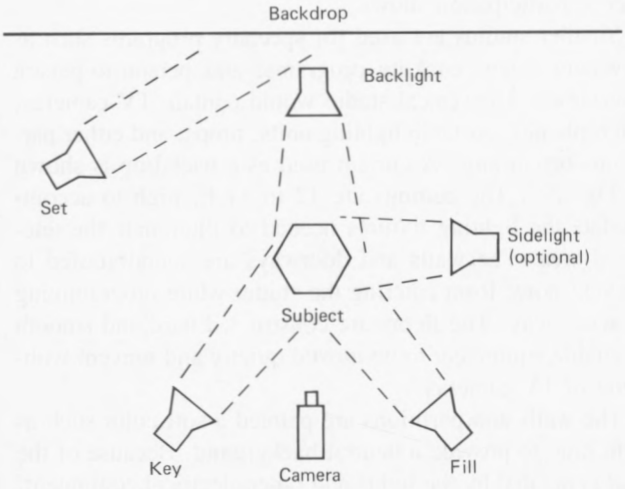

Fig. 2-5. Types and positions of lighting fixtures.

is space for the construction, assembling, and painting of sets.

2. *Dressing rooms*—rooms set aside for the application of makeup and changing costumes. There are separate rooms for male and female performers.
3. *Waiting room*—commonly known as the "green room." This room is where performers and guests who are to be interviewed, wait to be called to the studio for the show.
4. *Tape and film storage room*—for storage and editing of tape and film. The area must be extremely clean and free from dust. Rewinding equipment and viewers for editing both video tape and motion picture film would also be found in this room.
5. *Telecine room*—contains slide projectors and special projectors for showing motion picture film. The slide and motion picture projectors are placed so that their images will strike a special TV camera. In Fig. 2-6 we can see such an arrangement. In this arrangement mirrors are used to direct the images from the film projectors toward the TV camera. If both mirrors are pulled down, the image from the slide projector strikes the TV camera. If mirror 1 is raised, the image from film projector 1 will strike the TV camera. If mirror 1 is lowered and mirror 2 raised, the image from projector 2 will strike the TV camera.

Two film projectors are used to allow reels to be changed without interrupting the presentation. The slides contain spot announcements or commercials as well as pictures.

Also contained in the commercial TV station are the offices. These rooms are where the business affairs of the station are conducted. Areas are assigned to sales, advertisement, art, management, and public relations.

CONTROL ROOM

The control room is an area of highly specialized equipment and personnel located either close to or within the studio. A simple control room is seen in Figs. 2-7 and 2-8. The control room is where all the sound and picture signals are received, amplified, processed, and sent to the transmitter. At the transmitter the signals from the control room are sent out to the community or up to orbiting satellites. The major equipment found in a typical control room consists of the following:

1. *Video tape recorder-player*—used to record the sound and picture of a TV program. The program is recorded on video cassettes. The most common video cassettes used are the ½- and ¾-inch (-in.) sizes.
2. *Video switcher*—can accept signals from the studio cameras, video tape players, remote-location cameras, or the camera in the telecine room. The video switcher can then feed any of these signals to an individual monitor, thus enabling the director to choose a specific video signal to be used. Special effects included in the higher-priced video switchers include the ability to dissolve and superimpose images. Figure 2-9 shows a video switcher arrangement.
3. *Audio console*—receives inputs from microphones, turntables, and videotape players. Each sound signal is then fed to a meter that measures its level. This allows the volume level of each signal to be controlled by a separate volume control.

MICROPHONES

A microphone (sometimes informally referred to as a "mike") is a device that has the ability to sense sound energy and transform it into electrical impulses.

Before we begin our discussion of microphones, we will first examine how sound is produced. Looking at Fig. 2-10, we see a tuning fork that has been struck and is vibrating. As the prongs move back and forth, it alternately causes the air to be pushed together and spread apart. These variations in density move through the air molecules just

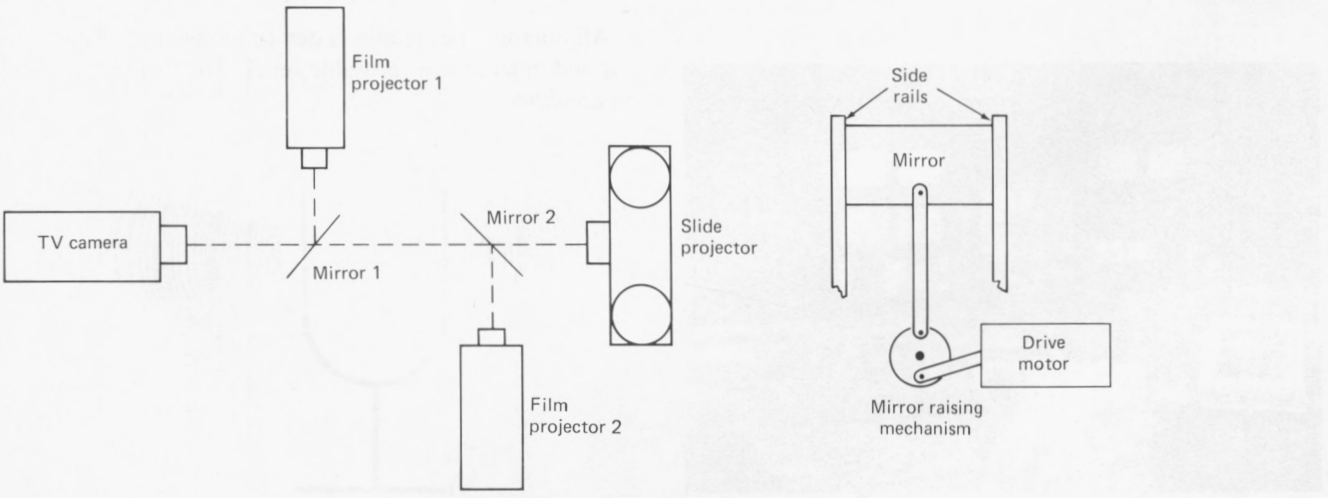

Fig. 2-6. Telecine room projectors. (*Mr. Gary Wallace*)

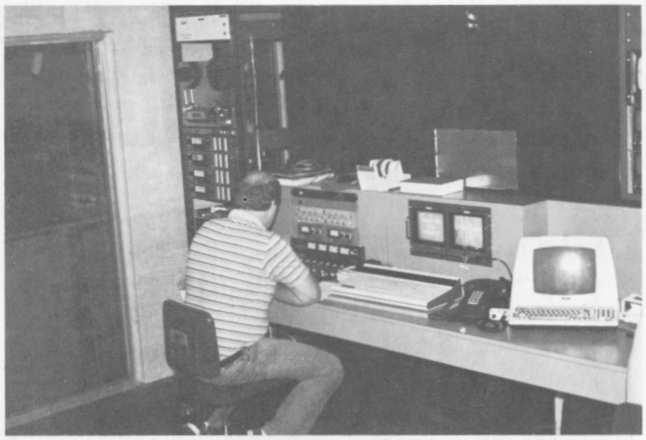

Fig. 2-7. Studio sound technician. (*KETC—St. Louis. Mo.*)

like waves in the ocean. When these waves of air strike the ear, the difference in pressure causes the sensation of hearing.

Categories of Microphones

The most common categories of microphones are:

1. *Desk microphones*—used during panel discussions
2. *Hand microphones*—generally used for interviewing people such as in a newscast
3. *Stand microphone*—used during performances by singers or comedians
4. *Lavalier microphone*—a microphone that hangs from the neck of the performer, allowing free movement during the performance
5. *Lapel microphone*—a microphone attached to the necktie or coat lapel; allows a wide range of movement
6. *Cordless microphone*—contains a small transmitter that sends the sound signal to a receiver. Although this microphone allows total freedom of movement, it will not work if taken too far from the receiver
7. *Shotgun microphone*—used to obtain sound from a very small, specific area, such as to pick up an individual voice within a crowd

Fig. 2-8. Studio video technician. (*KETC—St. Louis. Mo.*)

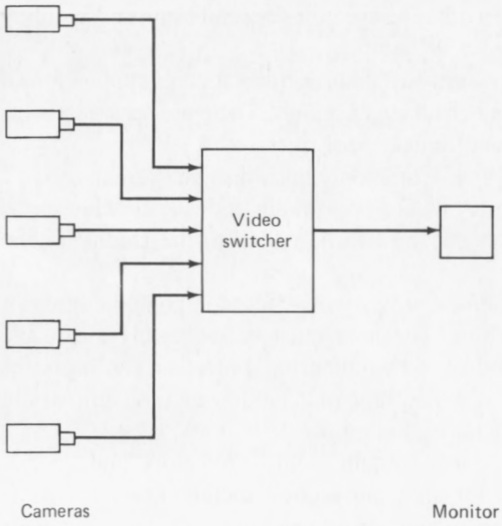

Fig. 2-9. A video switcher showing inputs and output.

Microphone Pickup Patterns

Not all microphones respond to sound from all directions. The different ways in which a microphone picks up the sound are called its *pickup pattern*. The basic microphone pickup patterns are the cardioid, omnidirectional, unidirectional, and directional (Fig. 2-11):

1. *Cardioid microphone*—picks up sound only from straight ahead and a small area on the left and right of the source
2. *Omnidirectional microphone*—picks up sound from all directions
3. *Unidirectional microphone*—picks up sound only from the front
4. *Directional microphone*—one type of directional microphone, known as a parabolic microphone, has a round curved dish behind it. The dish reflects the sound into the microphone making it highly directional.

All microphones require a device to take their small output and enlarge it to a usable level. This device is called an *amplifier*.

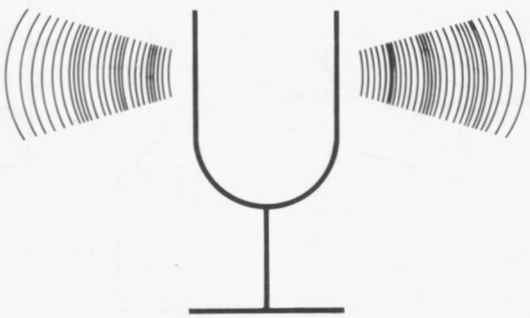

Fig. 2-10. Sound waves produced by a vibrating body.

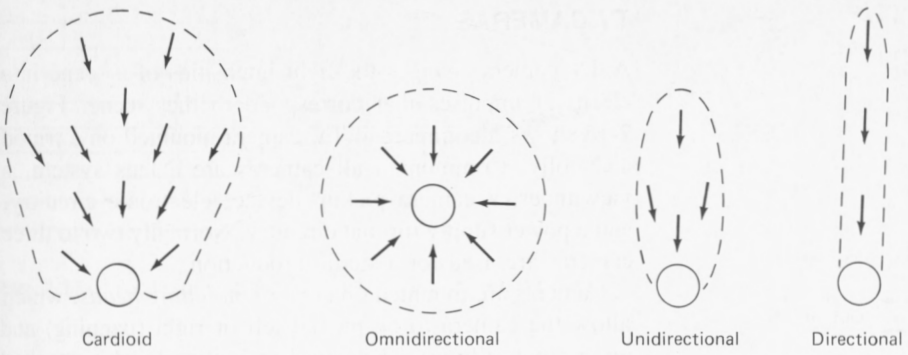

Fig. 2-11. Pickup patterns of microphones.

Classifications of Microphones

Microphones in use today fall under the classifications described in the following paragraphs.

Electret Condenser Microphone

Figure 2-12 shows the construction of an electret condenser microphone. The diaphragm and the stationary plate form a condenser (capacitor). The condenser microphone is part of a balanced circuit at the input of an amplifier. When sound waves strike the diaphragm, it vibrates. This vibration changes the spacing between the diaphragm and the stationary plate. This change in plate distance changes the capacitance of the balanced circuit. This imbalance causes the output of the amplifier to vary in step with the frequency and amplitude of the sound waves. The frequency response of the electret condenser microphone is 50 to 15,000 Hz. By changing the sound collecting head and element, this microphone can be rendered directional, unidirectional, or cardioid in its pickup pattern. The electret condenser microphone requires a 1.5-volt (-V) power source for operation.

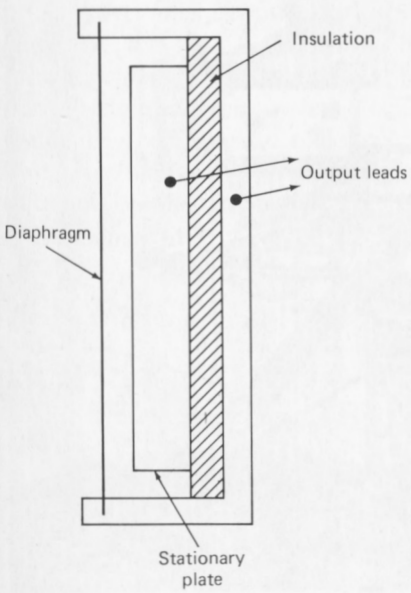

Fig. 2-12. Principle of operation of a condenser microhone.

Dynamic Microphone

Figure 2-13 shows the principal parts of a dynamic microphone. The dynamic microphone works on the principle of electromagnetic induction, which states that a voltage will be generated whenever a conductor is moved within a magnetic field. In the dynamic microphone, a diaphragm is connected to a coil of wire. When sound waves strike the diaphragm, this coil is moved in and out of the permanent magnetic field. This in-out movement causes a voltage that is in step with the sound wave variations.

As you will notice, the dynamic microphone does not require an external power source as the electret microphone did; this is a decided advantage. The dynamic microphone has a frequency response between 30 and 18,000 Hz, is lightweight, and has a low impedance.

Crystal Microphone

The principle of operation of the crystal microphone is called *piezoelectricity*. This is the property of some crystals to generate a voltage if a mechanical force is applied. Figure 2-14 shows the construction of a crystal microphone. In the device shown, a thin slice of crystal material is sandwiched between two thin metal plates. One of these plates is connected to a diaphragm. When sound waves strike this diaphragm, a small voltage is generated. This voltage variation

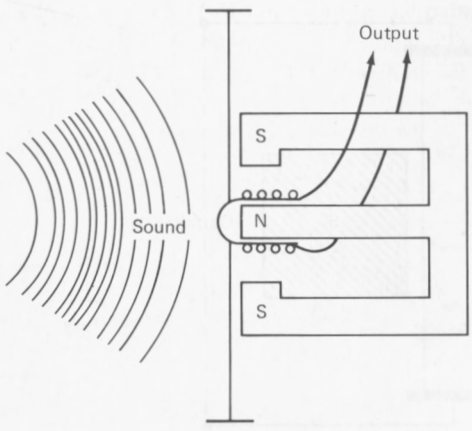

Fig. 2-13. Dynamic microphone construction.

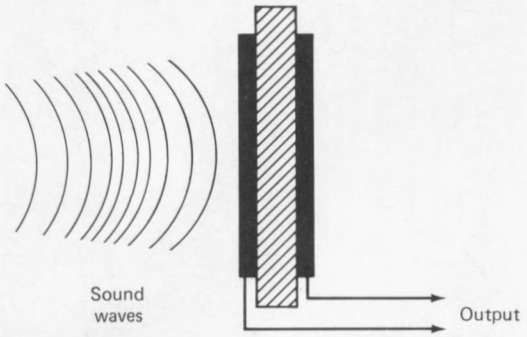

Fig. 2-14. Crystal microphone construction.

is in direct proportion to the sound intensities of the wave striking the diaphragm.

The crystal microphone has good frequency response, is easy to maintain, and does not require an external power source. The only disadvantage is that excessive heat [over 130 degrees Fahrenheit (130°F)] may damage the crystal. Therefore, when crystal microphones are used, exposure to high temperatures should be avoided.

Ceramic Microphone

The ceramic microphone is basically a crystal microphone with a ceramic material used in place of the crystalline material. The advantage of using a ceramic element is that moisture and temperature are not factors as they are in the crystal microphone.

Ribbon Microphone

The construction of the ribbon microphone consists of a small thin strip of aluminum alloy suspended between "north" and "south" magnetic poles. When the sound waves strike the ribbon, the ribbon vibrates. This movement generates a voltage that is in proportion to the intensity of the sound energy striking the ribbon. The construction of a ribbon microphone is shown in Fig. 2-15.

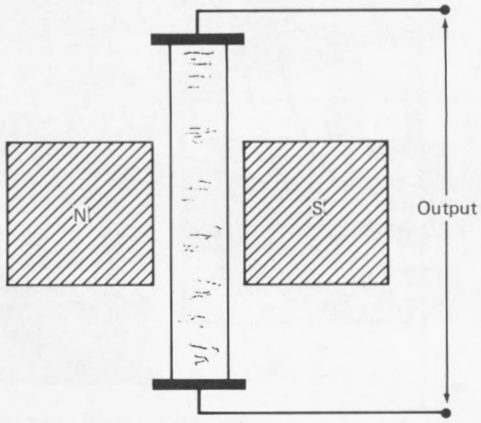

Fig. 2-15. Ribbon microphone construction.

TV CAMERAS

A TV camera changes the light intensities of a scene into electrical impulses that correspond to that scene. Figure 2-16 shows a commercial TV camera mounted on a tripod and dolly. Common to all cameras are a lens system, a viewfinder, a camera pickup device, electronic circuitry, and a power supply for that circuitry. Normally two to three cameras are used for a studio production.

Cameras are mounted on *camera mounting heads*, which allow the camera to be moved left or right (panning) and up or down (tilting). The camera mounting head is attached to either a tripod or a pedestal. A *tripod* is a three-legged device, and a *pedestal* is a single base that can be raised or lowered. Usually a pedestal is mounted on wheels. When a tripod-mounted camera is to be moved, a dolly is used. A "dolly" is a platform with wheels that has receptacles to fit the feet of the tripod.

The Lens System

Perhaps the most critical but least understood component of the camera is the lens system. The primary purpose of the lens system is to form a sharp image on the faceplate of the camera tube. How the lens accomplishes this can be seen by referring to the illustration of a simple lens shown in Fig. 2-17.*

When parallel rays of light enter a lens, the lens bends the rays, causing them to intersect at the *focal point*. The distance from the center of the lens to the focal point is referred to as the *focal length*. The focal length is determined primarily by the convexity (curvature) of the lens element (Fig. 2-18).

Somewhere beyond the focal point, the various rays of

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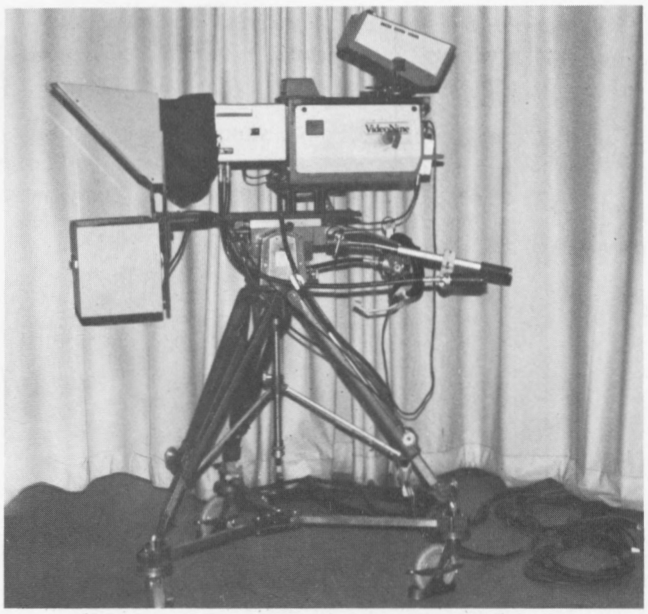


Fig. 2-16. Television camera. (*KETC—St. Louis. Mo.*)

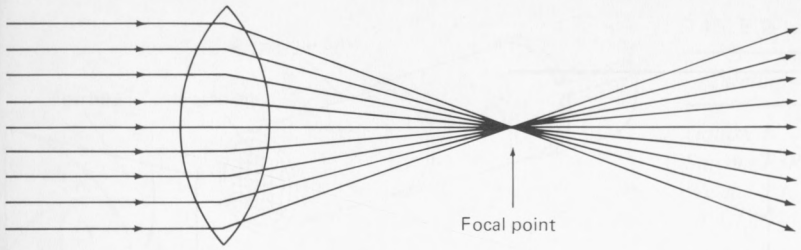


Fig. 2-17. Focal point of a lens. (*RCA Consumer Electronics*)

light from the lens will converge to form a sharp image (Fig. 2-19). The area in which the image is formed is called the *image plane*. Note that the image is inverted.

The focal length establishes the size of the image which will be formed. A lens of short focal length will produce a small image, and a lens of long focal length will produce a large image. Note also that the position at which the image is formed will change. Therefore, the position of the lens relative to the desired image plane must be adjusted to achieve a sharp image. This process is called *focusing*.

In the early camera lenses, focus was manually adjusted by turning a focus ring which moved the lens. In the present cameras, focusing can be automatically controlled by either an ultrasonic sound or an infrared light system. In the ultrasonic system (Fig. 2-20), sound waves are emitted, strike an object, and are reflected back to a receiver. The time interval between the signal being emitted and its reception is measured and the distance calculated. An electric motor then adjusts the focus ring to the correct focal point.

Adding to this complexity is the variable focal length or "zoom" lens system. In its simplest form, the lens consists of three individual elements: an objective lens, a variable lens, and a compensator lens (Fig. 2-21). The objective lens forms the image in a manner similar to that of a fixed-lens system. The variable lens is concave, however, and this lens bends the light rays in the opposite direction from the objective lens. The effect is to extend the focal length of the objective lens. Light rays are finally focused on the desired location by the compensator lens system. To summarize, in a zoom lens system, focus is achieved by adjusting the distance between the objective and the variable lenses, and the focal length is changed by varying the distance between the variable and compensator lenses.

The amount of light passing through the lens to the camera tube plays an important role in image reproduction. Although the camera tube responds to an extremely wide range of light, it is necessary to place an adjustable opening, or aperture, in front of it. The aperture prevents *overexposure,* which can damage its sensitive surface. In extreme cases, excessive amounts of light can burn an image into the surface of the camera tube. The aperture is constructed of sliding metal vanes forming an opening called the *iris* (Fig. 2-22).

Most cameras are equipped with an automatic iris control which assures correct iris settings under normal lighting conditions. For increased flexibility, a manual iris control may be added. This control allows the camera operator to open or close the iris to compensate for scenes with high contrast or backlighting. Such lighting may tend to "fool" the automatic iris system, thus causing the desired image to appear either too bright or too dark.

A measure of the amount of light passed by a lens system and its iris is the F number. The F number is also a measure of lens efficiency. For any given focal length, the larger the lens opening that can be utilized, the brighter the image. Normal lens F numbers range between F_1 and F_2.

The longer the focal length of the lens system, the lower the lens efficiency. This is because the lens passes a narrower angle or "zone" of light.

The center portion of a properly designed lens produces the sharpest and highest quality images. This is because the center portion bends the light rays the least amount and is relatively free from lensing errors. Also, for essentially the same reasons, the depth of field improves with smaller iris apertures. The depth of field is that area where objects located at different distances from the camera will appear in focus. The best quality images and depth of field for any given focal length are produced with small iris openings.

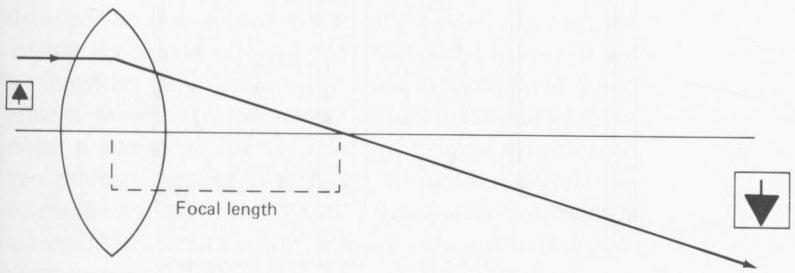


Fig. 2-18. Focal length of a lens. Note that the image is reversed. (*RCA Consumer Electronics*)

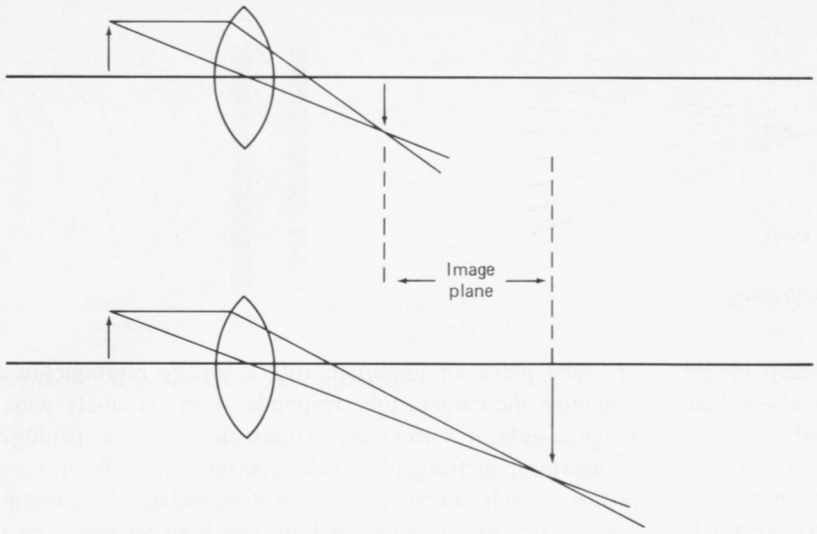


Fig. 2-19. Image plane of a lens. (*RCA Consumer Electronics*)

Viewfinders

Viewfinders are designed to provide the camera operator with a view of the subject. The three basic types of viewfinders in use today are described in the following paragraphs.

Optical Viewfinder

The optical viewfinder is actually a small lens system usually mounted on the top of the camera. This system gives the camera operator the ability to see the general area covered by the camera. Most optical viewfinders, however, have the inherent problem of *parallax error*, or not seeing precisely what the camera sees. Because of its heightened position, the viewfinder sees the subject at an angle different from that at which the camera lens does. This makes the optical viewfinder almost useless in close-up shooting.

Through-the-Lens Viewfinder

This system is similar to that found on 35-millimeter (-mm) still cameras. In the through-the-lens system, the image the lens sees is reflected up to the viewfinder, eliminating parallax error. Although a step up from the optical viewfinder, this viewfinder does not provide any camera operating information to the operator. It also has the disadvantage of reducing the total amount of light available to the camera pickup tube.

Electronic Viewfinder

The electronic viewfinder is by far the most sophisticated viewing system to be developed for the camera. This system incorporates a small video monitor which provides an exact indication of what the camera is viewing. The electronic viewfinder can inform the operator on the status of power consumption, the amount of light needed for satisfactory operation, the speed of the zoom lens, and the white balance setting. The camera is said to have the proper white balance when it will produce a neutral white under the existing lighting conditions.

This information is displayed by numbers and letters on the screen. An added benefit of this system is that it can be used as a playback monitor when utilized for videotaping.

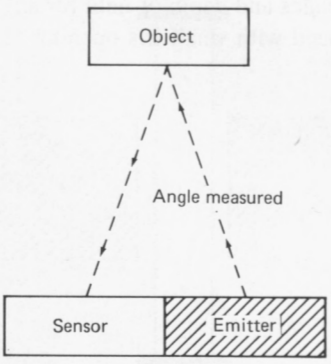


Fig. 2-20. Principle of operation of an ultrasonic or infrared automatic focusing system. (*RCA Consumer Electronics*)

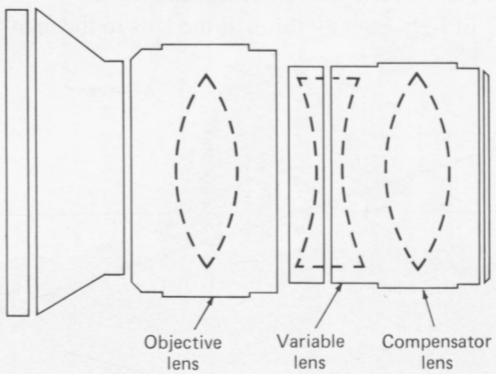


Fig. 2-21. Compound lens system. (*RCA Consumer Electronics*)

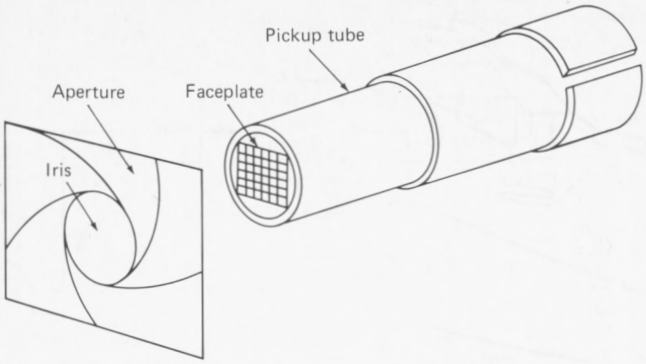


Fig. 2-22. Aperture in front of a pickup tube. (*RCA Consumer Electronics*)

THE CATV SATELLITE SYSTEM

Before we study the CATV satellite system, let us first take a look at the history of earth satellites.

On October 4, 1957 a series of beeps were heard coming from an orbiting satellite called *Sputnik*. This earth satellite had been launched by the Soviet Union and was working its way across the skies.

In an attempt to match that accomplishment, on February 1, 1958 the United States orbited an earth satellite called *Explorer I*. On August 12, 1960 a large aluminized balloon was sent into space so that scientists could bounce microwave signals off its surface. To receive these reflected signals, 100-ft antennas were needed. These massive antennas weighed 250 to 300 tons. On July 10, 1962 a satellite was launched that not only received the signal and then retransmitted it, but actually amplified it as well. Unfortunately, it remained operational only until November, when it experienced problems.

On August 31, 1962 Congress enacted the Communication Satellite Act. This act called for a global commercial communication satellite system to be established as soon as possible. Within 6 months the Communication Satellite Corporation (COMSAT) was formed to meet this mandate.

A satellite placed in orbit 22,275 mi above the earth's equator orbits the earth in a time period equal to that of the earth's rotation—24 h. Such a satellite is referred to as a *synchronous geostationary satellite*. It is synchronous because its orbit is synchronized to the earth's rotation. It is geostationary because it appears to be in the same position with respect to a point on the earth. This greatly reduces the sophistication needed to track the satellite. In fact, the satellite needs to be repositioned (this is done with on-board jet thrusters) only occasionally. Life expectancy of a satellite is governed by the amount of fuel it can carry for on-board positioning. The net result of using a synchronous geostationary satellite is that an earth station antenna can be made stationary. This yields a tremendous cost savings compared to an earth station antenna that must track a non-synchronous satellite.

Table 2-1 lists the name and location of some of the current domestic satellites that serve North America.

TABLE 2-1. Principal Satellites used in CATV

Satellite	*Location (West Long)*
Galaxy 1	134°
Satcom F3R	131°
Westar 5	122.5°
Anik D	104.5°
Westar 4	99°
Satcom F4	83°

In orbit, a satellite and the earth form an angle of just over 17° degrees (17°). To allow for some errors in tracking, a satellite antenna radiating a beam of energy at an angle of 19° (Fig. 2-23) would cover the exposed face of the earth. If the satellite is to be used to cover only a small geographic area, the beam can be made narrower, which would increase its strength. At present, the minimum angular separation of satellites is 3°. This minimum separation is limited by the ability of the earth station to keep the signals apart. In the future, with advanced technology, a separation of 2° or less will be possible. For a given transmitter output power, improvement in the design of an antenna will provide a greater effective radiated power (ERP). Figure 2-24 shows the nominal ERP that a satellite has in the United States. A contour plot like that shown in Fig. 2-24 is sometimes referred to as the "footprint" of the satellite.

For commercial satellite communications, a band of frequencies 500 MHz wide has been allocated in the 4- and

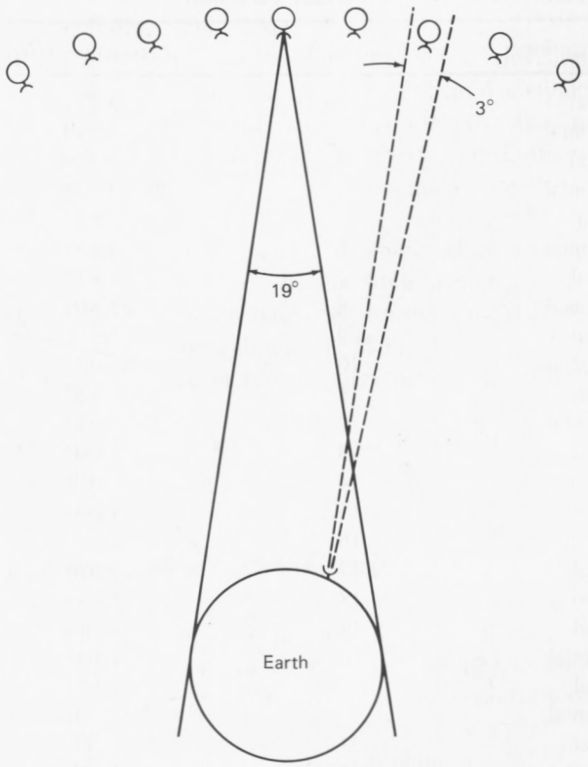


Fig. 2-23. Beam width of earth and satellite dish antennas.

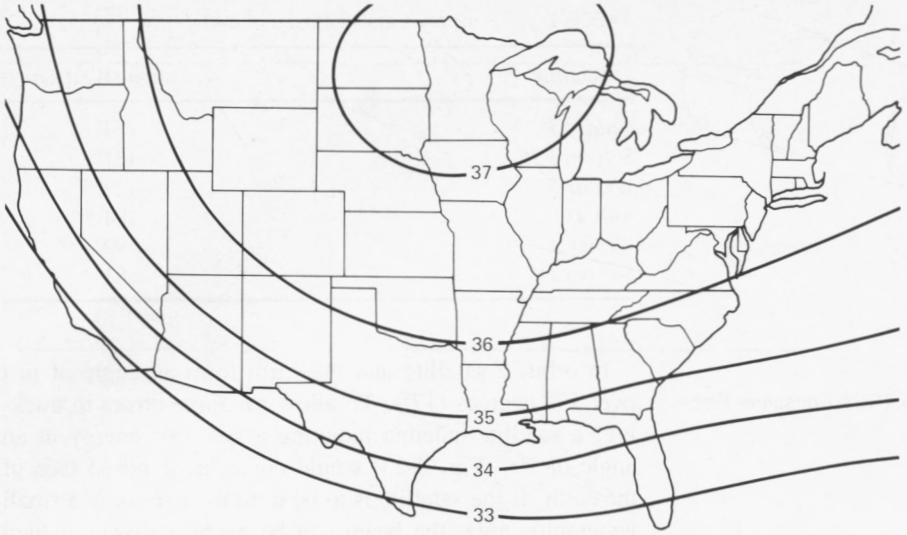


Fig. 2-24. Effective radiated power contour lines of a satellite transponder.

6-GHz frequency bands (3.7 to 4.2 GHz and 5.925 to 6.425 GHz) (1 MHz is equal to 10^6 Hz, and 1 GHz is equal to 10^9 Hz). The 4-GHz band is used to send information from the satellite to the earth station (downlinking), and the 6-GHz band is used to send information from the earth to the satellite (uplinking).

A transponder is a transmitter-receiver combination that receives a signal and retransmits it at a different carrier frequency. Most CATV satellites have 24 channels available. Each transponder occupies a frequency band 36 MHz wide with a 4-MHz guard band between transponder frequency assignments. To accommodate 24 CATV signals in the allocated 500-MHz bandwidth, both vertical and horizontal antenna polarizations are used. The use of both horizontal and vertical polarization allows 40-Mhz channels between similarly polarized signals as shown in Table 2-2. The term *polarization* refers to the way energy is radiated from the antenna.

TABLE 2-2. CATV Channels on *SATCOM F3R*

Polarization	*Channel No.*	*Frequency, GHz*
Vertical	1	3.720
Horizontal	2	3.740
Vertical	3	3.760
Horizontal	4	3.780
Vertical	5	3.800
Horizontal	6	3.820
Vertical	7	3.840
Horizontal	8	3.860
Vertical	9	3.880
Horizontal	10	3.900
Vertical	11	3.920
Horizontal	12	3.940
Vertical	13	3.960
Horizontal	14	3.980
Vertical	15	4.000
Horizontal	16	4.020
Vertical	17	4.040
Horizontal	18	4.060
Vertical	19	4.080
Horizontal	20	4.100
Vertical	21	4.120
Horizontal	22	4.140
Vertical	23	4.160
Horizontal	24	4.180

Figure 2-25 shows a simple earth station consisting of an antenna, a low-noise amplifier (LNA), and a video receiver. The antenna most commonly used is the parabolic reflector type (covered in Chapter 3).

To improve the signal-to-noise ratio (the ratio of the noise level to that of the signal) at the head-end of a CATV system, the LNA is mounted on the antenna structure.

The video receiver is connected to the coaxial cable of the LNA and should be located as close as possible to the antenna. Power for the LNA can be over either the same coaxial cable or a separate cable. The receiver is used to select the desired incoming 4-GHz signal and then reduce it to a more easily handled frequency. The output of the receiver contains both the sound and picture portions of the program.

Additional video programs carried by other transponders on the same satellite may also be received simply by inserting a power divider (signal splitter) in the coaxial cable immediately in front of the receiver and adding additional receivers. No changes to the antenna or LNA are required, provided all programs being received are carried on transponders with the same polarization. To receive programs

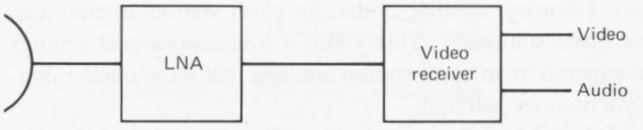


Fig. 2-25. Simple earth station utilizing a single-channel receiver.

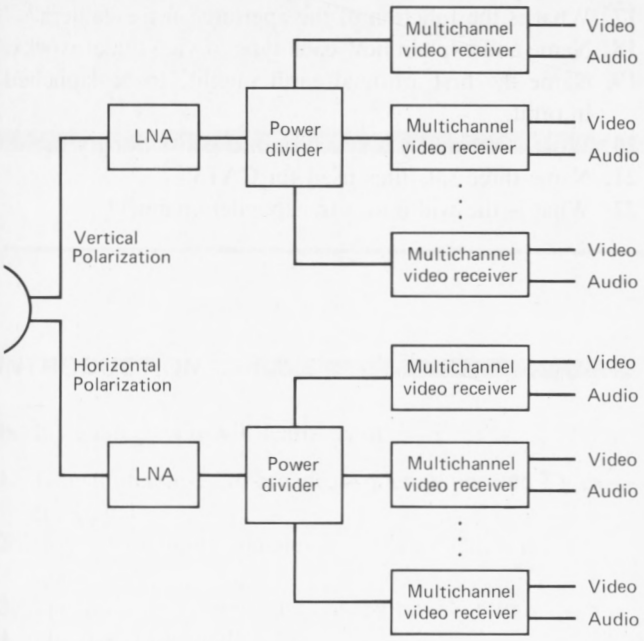


Fig. 2-26. An earth station utilizing multichannel receivers and dual polarization.

carried on transponders with the opposite polarization, an earth station must be equipped with a dual-polarized feed and a second LNA and coaxial cable run as shown in Fig. 2-26.

SUMMARY

1. The signal origination site is either a commercial TV station, a satellite programming source that sends signals to earth satellites for rebroadcast, or a CATV system.
2. These sites incorporate (*a*) studios, (*b*) auxiliary rooms, (*c*) a control room, (*d*) transmitters, and (*e*) an antenna system.
3. Most commercial TV stations contain facilities for live broadcasting as well as taped programming.
4. Because of the need for sufficient light for the TV camera, lighting fixtures are installed in the ceiling of the studio on a grid structure.
5. The types of lighting used in TV production are (*a*) backlights, (*b*) fill lights, (*c*) key lights, and (*d*) set lights.
6. Graphics are used in TV production in the following ways: (*a*) titles for people being interviewed, (*b*) charts for visual emphasis, and (*c*) pictures to be superimposed during newscasting.
7. In addition to the studio, other rooms called auxiliary rooms are needed for TV production. Some of the more common auxiliary rooms are (*a*) prop storage room, (*b*) dressing rooms for men and women, (*c*) guest waiting room, (*d*) tape and film storage rooms, (*e*) the telecine room, and (*f*) business offices.
8. A telecine room is used for slide and movie film projection onto a special TV camera.
9. The control room is truly the nerve center of a TV production and contains specialized equipment such as (*a*) video tape recorders and players, (*b*) video switcher, (*c*) an audio console, and (*d*) monitors.
10. Microphones are devices that change sound energy into electrical energy.
11. Microphones fall into the following categories: (*a*) desk, (*b*) hand, (*c*) stand, (*d*) lavalier, (*e*) lapel, (*f*) cordless, and (*g*) shotgun microphones.
12. The basic microphone pickup patterns are (*a*) cardioid, (*b*) directional, (*c*) omnidirectional, and (*d*) unidirectional.
13. The more common kinds of microphones are (*a*) electret condenser, (*b*) dynamic, (*c*) crystal, (*d*) ceramic, and (*e*) ribbon microphones.
14. Television cameras are devices that change light energy into electrical energy.
15. The lens system of the camera allows the image to be seen at various distances.
16. Lenses may be adjusted manually or changed automatically through the use of either an ultrasonic sound or infrared light system.
17. The three types of viewfinders found on television cameras in use today include (*a*) optical viewfinders—a simple lens system, (*b*) through the lens—the image is reflected by a mirror system, and (*c*) electronic viewfinder—utilizes a monitor mounted directly on the camera.
18. The first earth satellite was *Sputnik*, which was launched on October 4, 1957 by the Soviet Union.
19. The first satellite launched by the United States was *Explorer I* on February 1, 1958.
20. Satellites are in geostationary orbit, 22,275 mi above the equator.
21. An earth station is made up of an antenna, an LNA, and a video receiver.

REVIEW QUESTIONS

1. Describe a typical commercial TV studio.
2. Name five items contained in a TV studio.
3. Why are the floors constructed hard in a studio?
4. What is a grid?
5. Name three types of lighting and their purpose.
6. Name four qualities of good graphics.
7. Why is a special camera needed in the telecine room?
8. Why are two movie projectors used in the telecine room?
9. Name three pieces of equipment in a control room and their use.
10. Name five categories of microphones.
11. Name four classifications of microphones.

12. Name three microphone pickup patterns.
13. How does a dynamic microphone change sound energy into electrical energy?
14. Define the focal point of a lens.
15. Explain one way in which a lens may be adjusted automatically.
16. Explain how a zoom lens system operates.
17. What is the function of the aperture on the camera?
18. Name and explain how each type of viewfinder works.
19. Name the first artificial earth satellite to be launched in orbit.
20. What is meant by a synchronized geostationary orbit?
21. Name three satellites used for CATV.
22. What is the width of a transponder channel?

3
CHAPTER
SIGNAL TRANSMISSION

INTRODUCTION

In this chapter you will learn about:

1. Transmitters used to broadcast microphone and TV camera signals
2. How an antenna radiates electromagnetic energy into space
3. The way electromagnetic energy travels through space
4. The use of decibels
5. Selection of an antenna site
6. Antennas used in CATV

The basic instruments of signal transmission are the transmitter and the antenna. Electrical energy from the transmitter is converted into electromagnetic energy by the antenna and then radiated into space. This electromagnetic energy is in the form of radio waves, of which there are two basic components: ground waves and sky waves. A transmitter and its antenna form one link of a communications system. All that is needed to complete the system is a receiver and its antenna.

BASIC TRANSMITTERS

A transmitter may be a simple, low-power unit for sending voice messages, as in citizen's-band (CB) radio, or it may be a highly sophisticated unit utilizing thousands of watts of power for sending information (e.g., voice, music, TV pictures) simultaneously over long distances.

In commercial TV, the sound (audio) signal is frequency-modulated (FM), while the picture (video) signal is amplitude-modulated (AM). Modulation is the process of putting intelligence on a radio frequency (RF) carrier wave. In amplitude modulation, the *amplitude* of the carrier wave is varied above and below its normal value in accordance with the modulating signal. In frequency modulation, the *frequency* of the carrier wave is changed in accordance with the modulating signal. Basic transmitters include both the AM and FM types. A brief description of each type follows.

AM Transmitter

The block diagram of a simple AM transmitter and its waveform is shown in Fig. 3-1. The oscillator generates an RF carrier at a predetermined frequency and maintains it within required limits. The purpose of the buffer amplifier is to isolate the oscillator from the final stage, known as the *power amplifier*. This isolation improves the frequency stability of the transmitter. To illustrate how an AM transmitter operates, we will allow a microphone to furnish an audio signal to the modulator. The modulator then amplifies the audio signal to the amplitude necessary to fully modulate the carrier. The output of the modulator is applied to the power amplifier. The RF carrier and the modulating signal are combined in the power amplifier to produce an AM RF carrier output for transmission. After amplification by the power amplifier, the modulated RF carrier is sent through a transmission line to the antenna. In the absence of a modulating signal, a continuous RF carrier is radiated by the antenna. Amplitude-modulated transmitters are used to transmit the picture portion of a TV signal.

FM Transmitter

Figure 3-2 is the block diagram of an FM transmitter. To illustrate how this transmitter operates, an audio signal is applied to its modulator. Within the modulator is a solid-state device, known as a *varactor*. The purpose of the varactor is to change the frequency of the oscillator in step with the variations of the audio signal. With no modulating signal, the oscillator will generate a steady center frequency.

The output of the oscillator is fed to a frequency multiplier to increase the frequency and then to a power amplifier to increase its amplitude to the desired level for transmission. Also seen in Fig. 3-2 is the output waveform of an

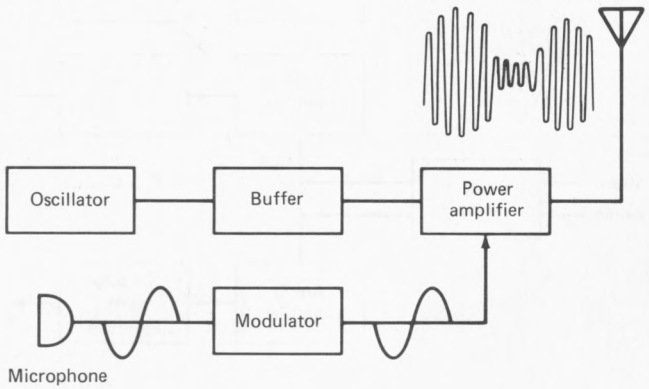


Fig. 3-1. AM transmitter block diagram.

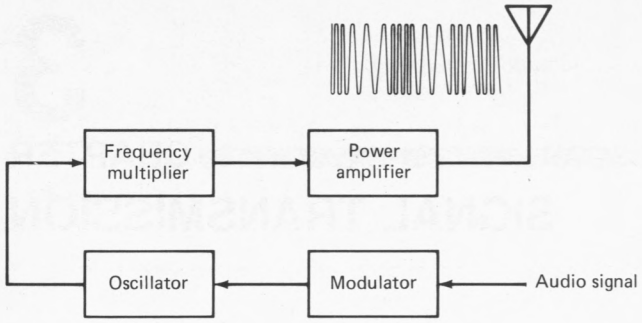


Fig. 3-2. FM transmitter block diagram.

FM transmitter. Frequency-modulated transmitters are used to transmit the sound portion of a TV signal.

THE DIPLEXER

In Fig. 3-3 we can see the audio and the video signals from the microphones and cameras as they travel through the control room en route to their respective transmitters. From the transmitters, the modulated signals go to a diplexer, where they enter the transmission line as separate signals to be radiated simultaneously by a common antenna.

The purpose of the diplexer is to allow the signals to mix without interfering with each other on the antenna.

ANTENNA RADIATION

An antenna can be defined as a conductor or a system of conductors used for either radiating electromagnetic energy into space or collecting electromagnetic energy from space. In effect, electrical energy from the transmitter is converted into electromagnetic energy by the antenna and radiated into space. On the reception end, electromagnetic energy is converted into electrical energy by the antenna and fed into the receiver.

Fortunately, separate antennas seldom are required for transmission and reception of radio energy. Any antenna transfers energy from space to its input receiver terminals with the same efficiency that it transfers energy from the output terminals of the transmitter into space—assuming, of course, that the same frequency is used in both cases. This property is known as *antenna reciprocity*. Antenna reciprocity is possible because antenna characteristics are essentially the same regardless of whether an antenna is sending or receiving electromagnetic energy.

To visualize how an antenna radiates energy, let us study the electrical properties of a capacitor that is connected to an AC generator. In Fig. 3-4 we can see that during the positive alternation, an electric field builds up from the center of the plates, outward toward their ends (Figs. 3-4*a* and 3-4*b*). As the field continues to build, it moves further and further beyond the physical limits of the capacitor plates and escapes into the surrounding space. This escape of energy can be seen in Fig. 3-4*c*. On the negative alternation, the electric field collapses, starting at the ends and moving inward toward the center of the plates. On the next alternation, the field again builds up as it did before. From this we can see that the electric field constantly moves along the plates of the capacitor as the polarity of the source changes.

If we were to connect two conductors to an alternating-current (AC) generator, we would have something resembling Fig. 3-5*a*. Notice the electric field between the two wires. If we were to bend the conductors until they were partially (Fig. 3-5*b*) and then fully (Fig. 3-5*c*) open, we would have what is known as a *center-fed, half-wave, dipole antenna*. The terms *full-wave, half-wave, quarter-wave,* and *eighth-wave* refer to the physical length of an antenna. Because frequency determines the length of an electromagnetic wave, to radiate or receive energy at this frequency, an antenna must be of the correct length. The length of a full-wave antenna is found by using the following formulas (the symbol for wavelength is the Greek letter lambda λ):

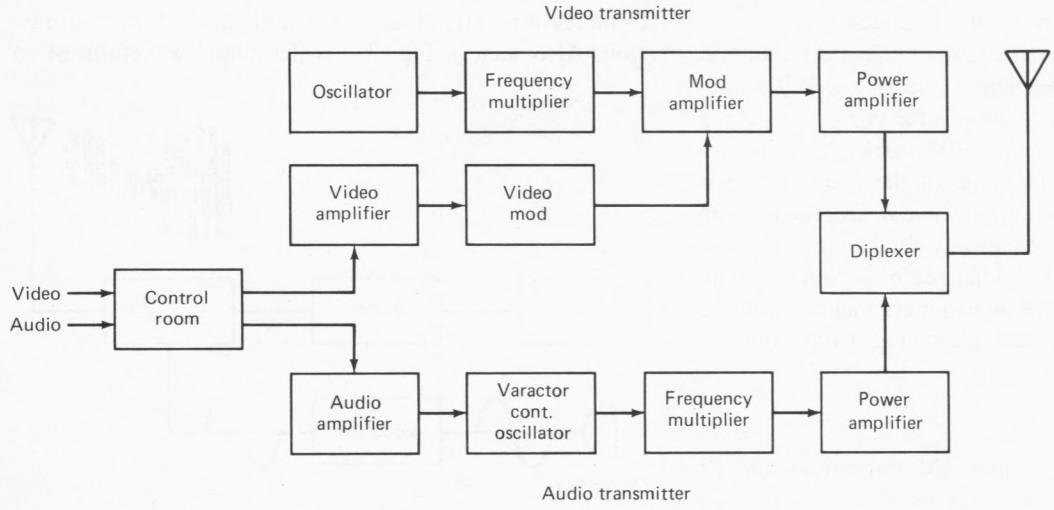


Fig. 3-3. Block diagram of TV transmission system.

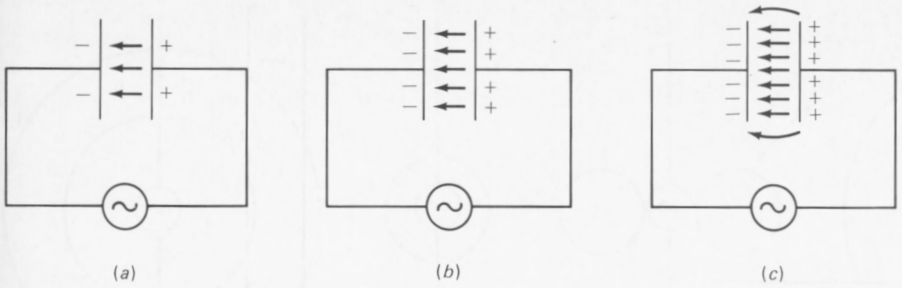


Fig. 3-4. Charge pattern of a capacitor.

$$\lambda \text{ (feet)} = \frac{984{,}000{,}000}{f} = \frac{984 \times 10^6}{f}$$

where λ is wavelength in feet and f is frequency in hertz. If frequency is given in kilohertz, we use

$$\lambda \text{ (feet)} = \frac{984{,}000}{f} = \frac{984 \times 10^3}{f}$$

If frequency is given in megahertz, we use

$$\lambda \text{ (feet)} = \frac{984}{f} = \frac{984 \times 10^0}{f}$$

From these formulas we can see that a full-wave antenna will be 19.68 ft long at 50 MHz. A half-wave antenna will be 9.84 ft, a quarter-wave antenna 4.92 ft and an eighth-wave antenna 2.46 ft long. The symbols used would be λ (full-wave), $\frac{1}{2}\lambda$ (half-wave), $\frac{1}{4}\lambda$ (quarter-wave), and $\frac{1}{8}\lambda$ (eighth-wave).

The dipole antenna is one of the most popular antennas used for the transmission and reception of radio waves. Because of distributed impedance, the current on a dipole antenna is 90° out of phase with the voltage. From Fig. 3-6 we can see the current and voltage distribution on a half-wave dipole antenna. This flow of current causes an electromagnetic field to be created whose magnitude and direction will reflect the voltage and frequency of the generator. The electromagnetic field will be at right angles to the antenna as shown in Fig. 3-7. For maximum efficiency, the two conductors of the dipole antenna should be one-quarter wavelength each.

Thus far we have shown the antenna in a horizontal position, but it will work equally well if placed vertically. Most vertical antennas use the earth as one half of its total length. Figure 3-8 shows a vertical center-fed dipole antenna using the earth as its other "leg."

Figure 3-9 gives a simple picture of an electric field detaching itself from the antenna. The magnetic field will not be considered, although it is present nevertheless. In Fig. 3-9*a* the electric field has maximum intensity. The lines of force begin at the positively charged end of the antenna and extend to the negatively charged end. Note that the outer lines are stretched away from the inner ones. This is due to the repelling force between lines of force in the same direction. As the voltage drops, the separated charges come together, and the ends of the lines move toward the center of the dipole as shown in Fig. 3-9*b*. However, since lines of force in the same direction repel each other, the center of the line is still being held out.

As the voltage approaches zero, some of the lines collapse back into the dipole, but in others the ends of the lines join to form a complete loop. Notice the direction of these lines of force next to the dipole in Fig. 3-9*c*. At this point the voltage on the antenna is zero. As the charge begins to build up in the opposite direction, electrical lines of force again begin at the positive end of the antenna and stretch to the negative end (Fig. 3-9*d*). Because these lines of force are in the same direction as the sides of the closed loops next to the antenna, they repel the closed loops and force them out into space at the speed of light.

One important factor about radiation is that its rate varies with frequency. At lower frequencies, such as at 60-Hz power frequencies, voltage on the antenna changes so slowly that the component of energy radiated is extremely small and of no practical value. At higher frequencies, such as

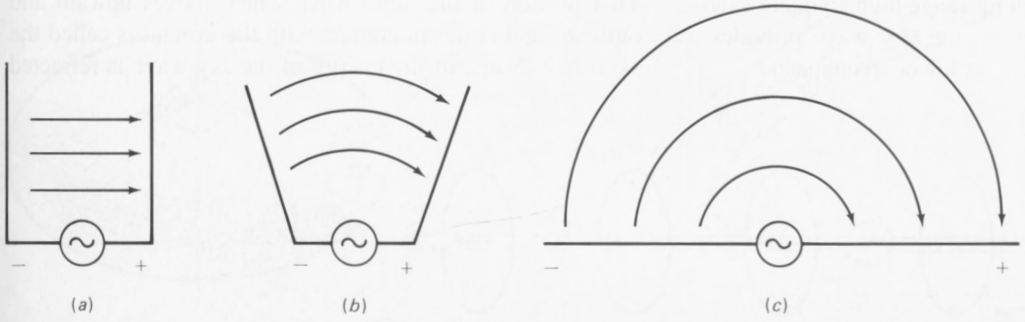


Fig. 3-5. Expansion of electric lines of force on two conductors.

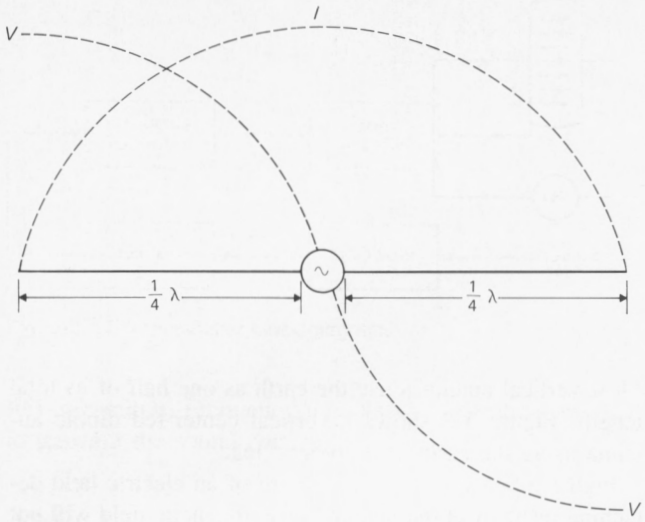


Fig. 3-6. Current and voltage distribution on a half-wave center-fed dipole antenna.

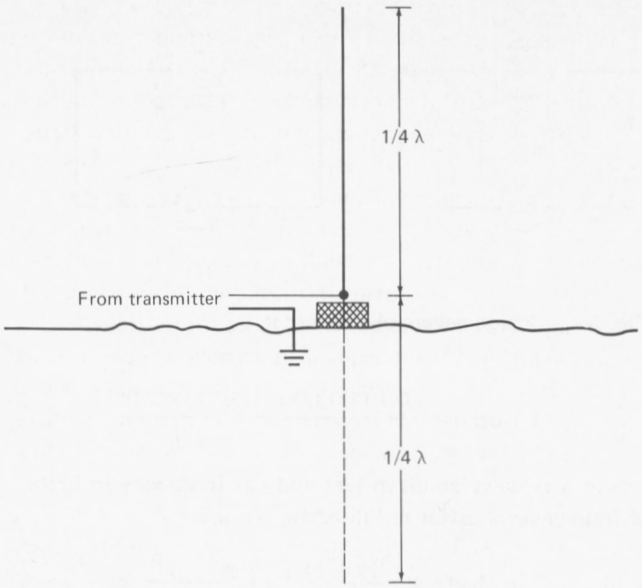


Fig. 3-8. Vertical half-wave dipole antenna.

50,000 Hz (50 kHz) and above, the radiated energy is sufficient to meet communications requirements.

WAVE PROPAGATION

Radio waves propagated into space are considered to be a radiant form of energy similar to light. Radio waves travel at the speed of light, which is 186,281.7 miles per second (mi/s) in free space. The theory of wave propagation as presented in this chapter, although greatly simplified, has been generally accepted.

When a radio wave leaves a vertical antenna, the field pattern of the wave is omnidirectional and resembles a huge doughnut lying on the ground with the antenna in the hole at the center, as seen in Fig. 3-10. Part of the wave moves outward in contact with the ground to form the *ground wave,* and the rest of the wave moves upward and outward to form the *sky wave,* as shown in Fig. 3-11. The ground and sky portions of the radio wave are responsible for two different methods of carrying the signals from transmitter to receiver. The ground wave is used for both short-range communications at high frequencies and long-range communications at low frequencies.

The sky wave is used for long-range high-frequency daylight communication. At night, the sky wave provides a means for long-range contacts at lower frequencies.

Ground Wave

Most of our daytime reception is provided by ground waves. As it passes over and through the ground, this wave induces a voltage in the earth, setting up currents. The energy used to establish these currents is absorbed from the ground wave, thereby weakening the wave as it moves away from the transmitting antenna. Increasing the frequency rapidly increases the attenuation so that ground-wave transmission is limited to relatively low frequencies. Some transmitters are able to transmit long-range ground-waves transmissions by using frequencies between 18 and 300 kHz with extremely high power.

Since the electrical properties of the earth along which the ground wave travels are relatively constant, the signal strength from a given station at a given point is nearly constant. This applies essentially in all localities except those having distinct rainy and dry seasons, where the difference in the amount of moisture causes the conductivity of the soil to change. The strength of a ground wave is also affected by structures such as buildings and bridges.

Sky Wave

That portion of the radio wave which moves upward and outward and is not in contact with the ground is called the *sky wave*. Some of the energy of the sky wave is refracted

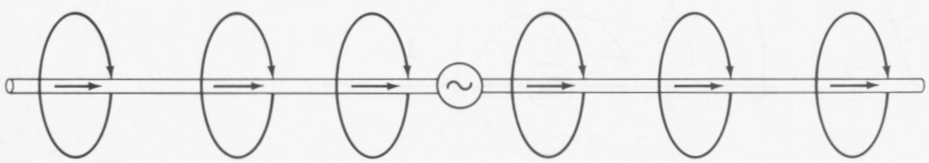


Fig. 3-7. Electromagnetic field around a half-wave center-fed dipole antenna.

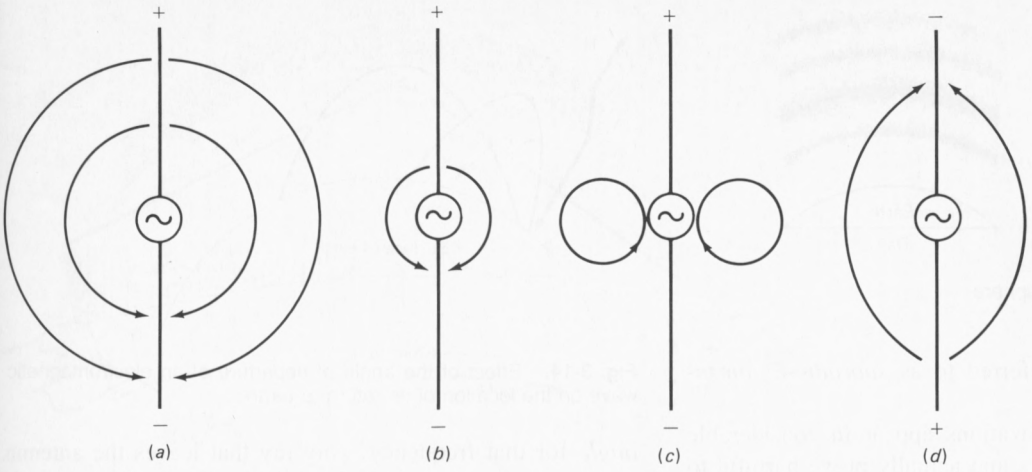


Fig. 3-9. An electric field detaching itself from an antenna.

(bent) by the ionosphere so that it comes back toward the earth. A receiver located in the vicinity of the returning sky wave will receive strong signals even though it may be located several hundred miles beyond the range of the ground wave.

Ionosphere

The ionosphere is found in the rarefied atmosphere approximately 40 to 200 mi above the earth. It differs from other atmospheric strata in that it contains a much higher number of positive and negative ions. (An ion is an unbalanced atomic particle.) The rotation of the earth on its axis, the seasons, and the development of sunspots all affect the number of ions present in the ionosphere, and these, in turn, affect the quality and distance of electronic transmissions. At altitudes below 40 mi or above 350 mi, air particles are far too sparse to permit large-scale energy transfer.

Densities of ionization at different heights make the ionosphere appear to have layers. Actually, there is thought to be no sharp dividing line between layers, but for the purpose of discussion, we will accept the following values. The ionized atmosphere at an altitude of 40 to 50 mi is called the *D layer*. Its ionization is low, and it has little effect on the propagation of radio waves except for the absorption of energy from the waves as they pass through it. The *D* layer is present only during the day.

The band of atmosphere at altitudes between 50 and 90 mi contains the *E layer*. It is a well defined band with greatest density at an altitude of about 70 mi. This layer is strongest during daylight hours and is also present, but much weaker, at night. The maximum density of the *E* layer appears at about noon local time.

The *F* layer extends approximately from the 90-mi level to the upper limits of the ionosphere. At night only one *F* layer is present, but during the day, especially when the sun is high, this layer often separates into two parts, F_1 and F_2, as shown in Fig. 3-12. As a rule, the F_2 layer is at maximum density during early afternoon hours, but there are many notable exceptions of maximum F_2 density existing several hours later. Shortly after sunset, the F_1 and F_2 layers recombine into a single *F* layer.

In addition to the layers of ionized atmosphere that appear regularly, erratic patches of ionized atmosphere occur at *E*-layer heights in the manner that clouds appear in the

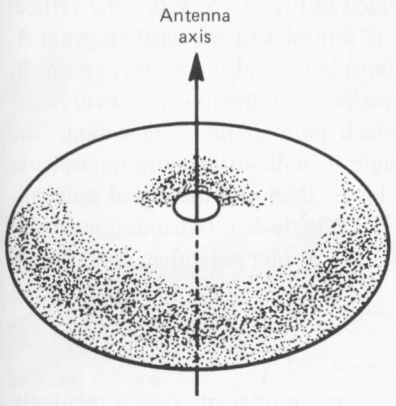


Fig. 3-10. Vertical antenna field pattern.

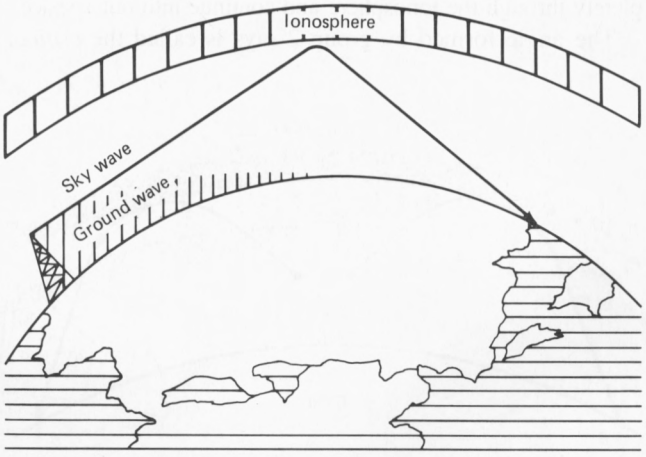


Fig. 3-11. Ground and sky waves.

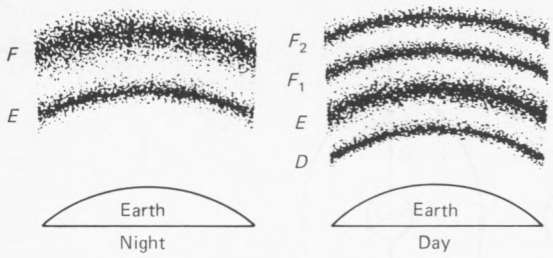


Fig. 3-12. Layers of the ionosphere.

sky. These patches are referred to as *sporadic-E ionizations*.

Sometimes sporadic ionizations appear in considerable strength at varying altitudes and actually prove harmful to electronic transmissions.

Effect of Ionosphere on the Sky Wave

The ionosphere has many characteristics. Some waves penetrate and pass entirely through it into space, never to return. Other waves penetrate but bend. Generally, the ionosphere acts as a conductor and absorbs energy in varying amounts from the wave. The ionosphere also acts as an electronic mirror and refracts (bends) the sky wave back to the earth, as illustrated in Fig. 3-13.

The ability of the ionosphere to return an electromagnetic wave to the earth depends on the angle at which the sky wave strikes the ionosphere, the frequency of the transmissions, and ion density. When the wave strikes the ionosphere at an angle, the wave begins to bend. If the frequency and angle are correct and the ionosphere is sufficiently dense, the wave will eventually emerge from the ionosphere and return to the earth. If a receiver is located near either of points *B* shown in Fig. 3-13, the transmission from point *A* will be received. The sky wave in Fig. 3-14 is assumed to be composed of rays that radiate from the antenna in three distinct groups that are identified according to their angle of elevation. The angle at which group 1 rays strike the ionosphere is too nearly vertical for the rays to be returned to earth. The rays are bent out of line but pass completely through the ionosphere and continue into outer space.

The angle formed by group 2 rays is called the *critical angle* for that frequency. Any ray that leaves the antenna at an angle greater than this angle (angle θ) will penetrate the ionosphere.

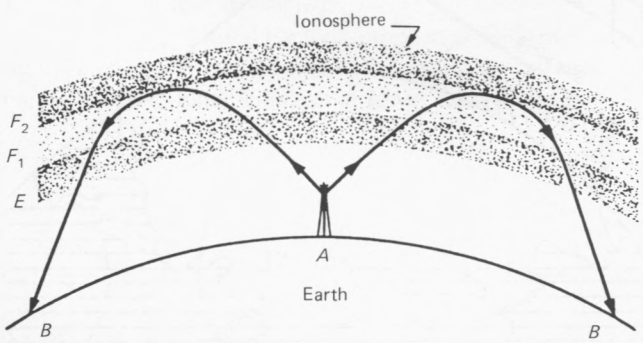


Fig. 3-13. Refraction of the sky wave by the ionosphere.

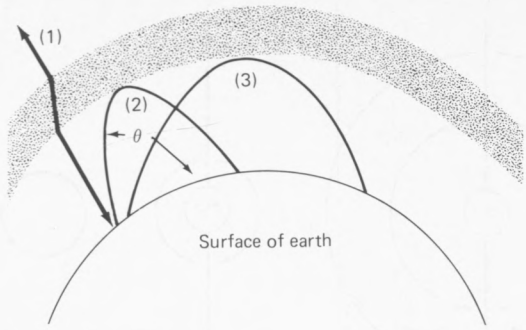


Fig. 3-14. Effect of the angle of departure of an electromagnetic wave on the location of its return to earth.

Group 3 rays strike the ionosphere at the smallest angle that will be refracted and still return to the earth. At any smaller angle the rays will be refracted but will not return to the earth.

The highest frequency that can be sent directly upward and still be refracted back to the earth is called the *critical frequency*. At sufficiently high frequencies, regardless of the angle at which the rays strike the ionosphere, the wave will not be returned to the earth. The critical frequency is not constant but varies from one locality to another, with the time of day, with the season of year, and with the sunspot cycle.

Skip Zone

Between the point where the ground wave is completely dissipated and the point where the first sky wave returns, no signal will be heard. This area is called the *skip zone* (Fig. 3-15). The skip zone for the lower high frequencies (3 to 9 MHz) will be greater at night than during the day. Skip-zone effects can be minimized by utilizing lower frequencies for nighttime communications. As a general rule as the frequency decreases, the skip distance decreases.

Multiple-Hop Transmission

The sky-wave path of a signal radiated at two different vertical angles is illustrated in Fig. 3-16. When the vertical angle is θ_1, the signal is returned to the earth at point *A*, reflected back to the ionosphere, and reappears at point *B*. If the same signal is transmitted at the lower vertical radiation angle θ_2, it can reach point *B* in a single hop. The signal transmitted at angle θ_1 will suffer more ionospheric and ground absorption losses than will the signal transmitted at angle θ_2. In general, single-hop transmissions result in greater field intensities at a distant point than do multiple-hop transmissions.

Fading

When a received signal varies in intensity over a relatively short period of time, the effect is known as *fading*, which

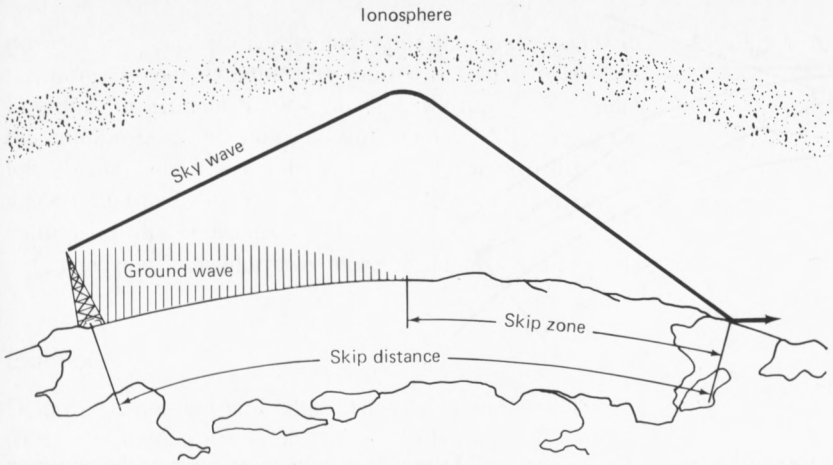


Fig. 3-15. Skip zone.

is one of the most troublesome problems encountered in electronic reception.

Several conditions can produce fading. One type of fading is common in areas where sky waves are utilized for transmission. Figure 3-17 shows two sky waves traveling in paths of different lengths. Because they arrive at different times, the waves will be out of phase. This out-of-phase condition produces a weakening of the signal. For example, if a portion of a transmitted wave arrived via the *E* layer and another portion arrived via the *F* layer, a complete cancellation of signal could occur if the waves arrived 180° out of phase and with equal amplitude. Usually, one signal is weaker than the other; therefore, a usable signal is obtained.

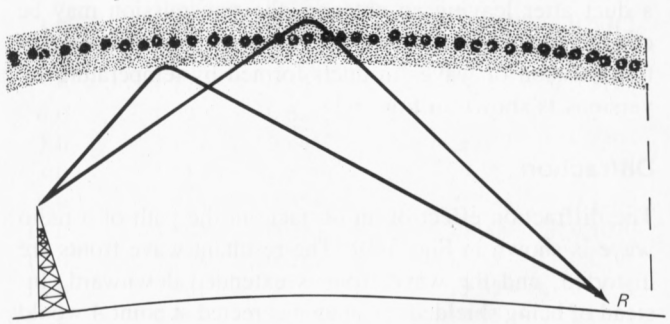


Fig. 3-17. Fading caused by arrival of two sky waves at the same point *R* out of phase.

Effect of Atmosphere on Transmission

Unusual ranges for very-high-frequency (VHF) and ultra-high-frequency (UHF) transmissions are sometimes caused by abnormal atmospheric conditions a few miles above the earth. Normally, the warmest air is found near the surface of a body of water. The air gradually becomes cooler as the altitude increases. Sometimes, unusual situations develop where warm layers of air are found above cooler layers. The condition is known as *temperature inversion*.

When a temperature inversion exists, the amount of refraction is different for the particles trapped within the boundaries from those outside them. These differences form channels or ducts that will conduct the radio waves many miles beyond the assumed normal range.

Sometimes these ducts are in contact with the water and may extend a few hundred feet into the air. At other times

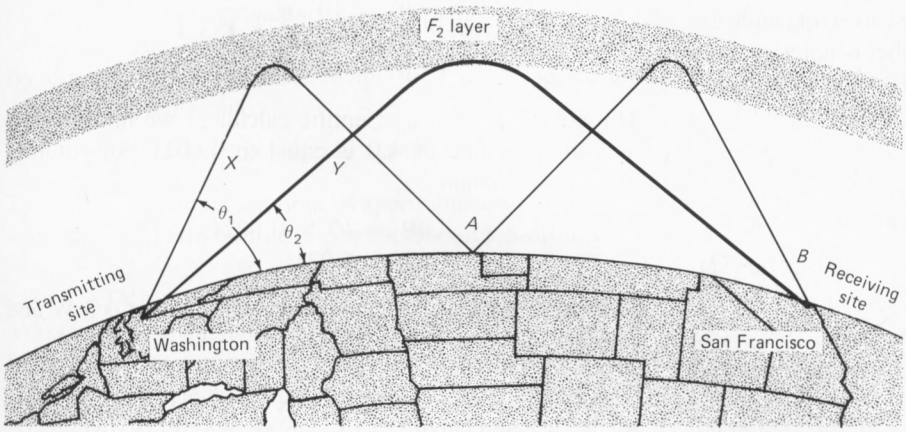


Fig. 3-16. Path of a sky-wave signal propagated at two different vertical angles.

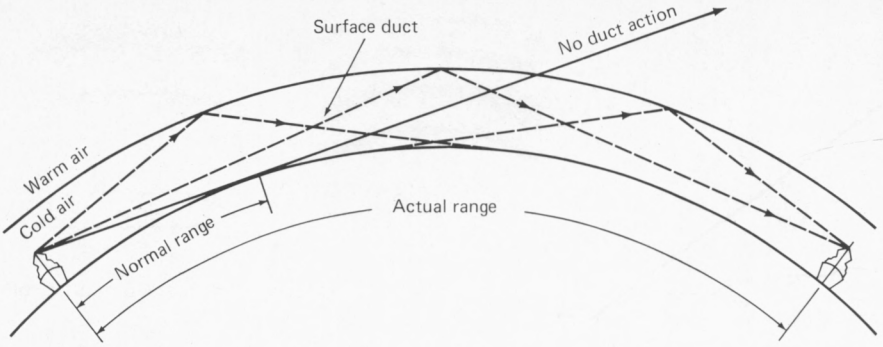


Fig. 3-18. Duct effect in high-frequency transmission.

the duct will start at an elevation of 500 to 1000 ft and extend an additional 500 to 1000 ft in the air.

If an antenna extends into the duct or if the wave enters a duct after leaving an antenna, the transmission may be conducted for a long distance. An example of this type of transmission of waves in ducts formed by temperature inversions is shown in Fig. 3-18.

Diffraction

The diffraction effect of an obstacle in the path of a radio wave is shown in Fig. 3-19. The resultant wave fronts are distorted, and the wave front is extended downward. Instead of being shielded, an antenna erected at point *A* would receive some energy from the transmitting antenna.

DECIBELS

Before we discuss the different types of antennas used in CATV systems, let us first consider the system of measurement used to compare antennas and amplifiers and to determine cable efficiency. The decibel is a convenient unit for expressing gain or loss of signal or finding relative power levels. *Gain* can be defined as the increase of signal power produced by an amplifying device; *loss* is power that is dissipated in a device or system. The major advantage in using decibels is that their values can be either added to determine gain or subtracted to determine loss. Therefore, the use of decibels eliminates the need to work with extremely small or large values. The decibel is not a quantity as is voltage, power, or current, but is equal to 10 times (for power) or 20 times (for voltage or current) the common logarithm of the ratio of these quantities.

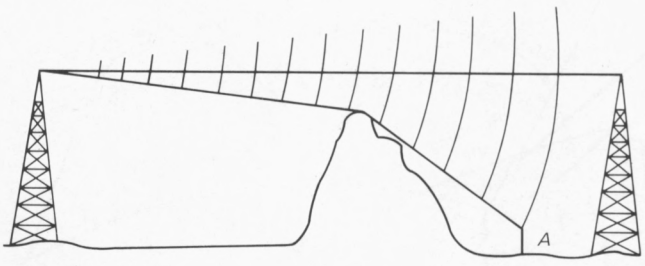


Fig. 3-19. Diffraction of transmitted energy by sharp edge of a mountain.

Decibels (dB) indicate *power ratios* by the formula

$$\text{dB (gain or loss)} = 10 \log_{10} \frac{P_1}{P_2}$$

Decibels indicate *voltage ratios* by the formula

$$\text{dB (gain or loss)} = 20 \log_{10} \frac{V_1}{V_2}$$

And *current ratios* by the formula

$$\text{dB (gain or loss)} = 20 \log_{10} \frac{I_1}{I_2}$$

where $\log_{10}$ is the common logarithm (base 10).

To see how decibels are calculated, let us study the following examples.

Example 1

Find the gain of an amplifier whose input signal is 3 watts (W) and output is 12 W.

Solution

Substituting our input and output values for P_1 and P_2 in the power formula, we obtain

$$\text{dB} = 10 \log_{10} \frac{12}{3}$$

$$\text{dB} = 10 \log_{10} 4$$

Through the use of a scientific calculator we find that the logarithmic value of 4.0 is equal to 0.6021. Substituting 0.6021, we obtain

$$\text{dB} = 10 \times 0.6021$$
$$\text{dB} = 6.021$$

Therefore, the gain of an amplifier whose input is 3 W and output is 12 W is 6.021-dB.

Another and much simpler way we could have found the answer would have been to use Table 3-1. To use this table, we must first determine the ratio of input power to output

power and then find the decibel value that corresponds to the ratio. In our example the ratio was found to be 4.0. Looking for a quantity close to this, we find 3.981 under the column labeled "Power Ratio—Gain." Moving to the left, we see that the decibel value is equal to 6 dB. The value found in Table 3-1 can be used when an approximate value is all that is needed.

Let us now consider two more examples, using Table 3-1.

Example 2

Determine the output value when a signal of 30 mV (0.03 V) enters a device that has a 3-dB loss.

Solution

After we find 3 in the column labeled "dB," we move to the right until we are under the column labeled "Current or Voltage Ratio—Loss." In this column we see that the ratio is 0.7079. By multiplying 0.7079 by the input value, we obtain 21.237 millivolts (mV) as the output voltage:

$$0.7079 \times 30 = 21.237$$

We now see that 21.237 mV of signal will be present at the output of a −3-dB device whose input was 30 mV.

Example 3

Calculate the input current of a device that has a 5.5-dB gain and whose output is 60 mA [0.06 ampere (A)].

Solution

Our first step is to find the ratio that is representative of 5.5 dB. Looking at Table 3-1, we see that 5 dB = 1.778 and 6 dB = 1.995; therefore, 5.5 dB must be approximately halfway between these two values. To find that amount, we subtract the smaller from the larger and divide by 2:

$$\begin{array}{r} 1.995 - 1.778 = 0.217 \\ 2\overline{)0.217} = 0.1085 \end{array}$$

When we add this to 1.778, we obtain 1.8865:

$$1.778 + 0.1085 = 1.8865$$

By dividing 1.8865 into the output of 60 mA, we obtain the input current value:

$$1.8865\overline{)60} = 31.805$$

Thus we can see that an input of approximately 31.805 mA is needed to obtain 60 mA of current from a 5.5-dB device.

In CATV a unit known as a dBmV is used to simplify working with small values of signal voltage. The term *dBmV* refers to the ratio of signal voltage measured in the 75-ohm (-Ω) coaxial cable that is used in CATV. The 0-dBmV level is defined as 1 mV (0.001 V) of signal present in the 75-Ω cable. Therefore, gain or loss can be compared to the 0-dBmV level. To measure dBmV units, an instrument known as a *signal level meter* is used. We will use dBmV units when we explore Chap. 8 (on CATV system analysis). The formula used to convert signal voltages to dBmV units is

$$\text{dBmV} = 20 \log_{10} (\text{signal voltage in millivolts})$$

For example, to convert a signal of 15 mV to dBmV units we set

$$\text{dBmV} = 20 \log_{10} 15 = 20 \times 1.176 = 23.52$$

The term *dBW* is used to indicate decibels referenced to 1 W. This unit was used in Fig. 2-24 to indicate the effective radiation power (ERP) of a satellite signal.

TABLE 3-1 Decibel Table (0 to 50 dB)

	Current or Voltage Ratio		*Power Ratio*	
dB	*Gain*	*Loss*	*Gain*	*Loss*
0.0	1.000	1.0000	1.000	1.0000
0.1	1.012	0.9886	1.023	0.9772
0.2	1.023	0.9772	1.047	0.9550
0.3	1.035	0.9661	1.072	0.9333
0.4	1.047	0.9550	1.096	0.9120
0.5	1.059	0.9441	1.122	0.8913
0.6	1.072	0.9333	1.148	0.8710
0.7	1.084	0.9226	1.175	0.8511
0.8	1.096	0.9120	1.202	0.8318
0.9	1.109	0.9016	1.230	0.8128
1.0	1.122	0.8913	1.259	0.7943
2.0	1.259	0.7943	1.585	0.6310
3.0	1.413	0.7079	1.995	0.5012
4.0	1.585	0.6310	2.512	0.3981
5.0	1.778	0.5623	3.162	0.3162
6.0	1.995	0.5012	3.981	0.2512
7.0	2.239	0.4467	5.012	0.1995
8.0	2.512	0.3981	6.310	0.1585
9.0	2.818	0.3548	7.943	0.1259
10.0	3.162	0.3162	10.000	0.1000
11.0	3.548	0.2818	12.59	0.07943
12.0	3.981	0.2512	15.85	0.06310
13.0	4.467	0.2239	19.95	0.05012
14.0	5.012	0.1995	25.12	0.03981
15.0	5.623	0.1778	31.62	0.03162
16.0	6.310	0.1585	39.81	0.02512
17.0	7.079	0.1413	50.12	0.01995
18.0	7.943	0.1259	63.10	0.01585
19.0	8.913	0.1122	79.43	0.01259
20.0	10.00	0.1000	100.00	0.01000
30.0	31.62	0.0316	1,000.00	0.0010
40.0	100.00	0.0100	10,000	0.0001
50.0	316.2	0.0032	100,000	0.00001

LOCATION OF THE ANTENNA SITE

To deliver the best picture and sound to the subscriber, a site must be found that will provide the cable system with the highest signal possible.

Some factors in the selection of an antenna site are:

1. The availability and strength of all the signals within that system.
2. The proximity of the site to the head-end facilities.
3. A location that has minimal interference from nearby microwave transmitters. (Figure 3-20 shows a poor antenna site location.)
4. The type of terrain (freedom from natural and structural obstacles—buildings, bridges, etc.).
5. A site that provides protection from rock slides, flooding, and lightning damage.
6. Vehicular access.
7. Adequate electrical power.

Once the site is selected, antenna heights are determined, and interference from local industry is investigated and eliminated if possible.

ANTENNA SPECIFICATIONS AND TYPES

Many different types of antennas are in use today within the CATV industry. A variety of antennas may be seen in Fig. 1-5.

Antenna specifications are the mechanical and electrical performance characteristics that the manufacturer furnishes to the purchaser of an antenna. Along with the specifications, manufacturers also provide sheets containing radiation patterns of the antenna. Figure 3-21 shows an antenna pattern with its principal parts identified.

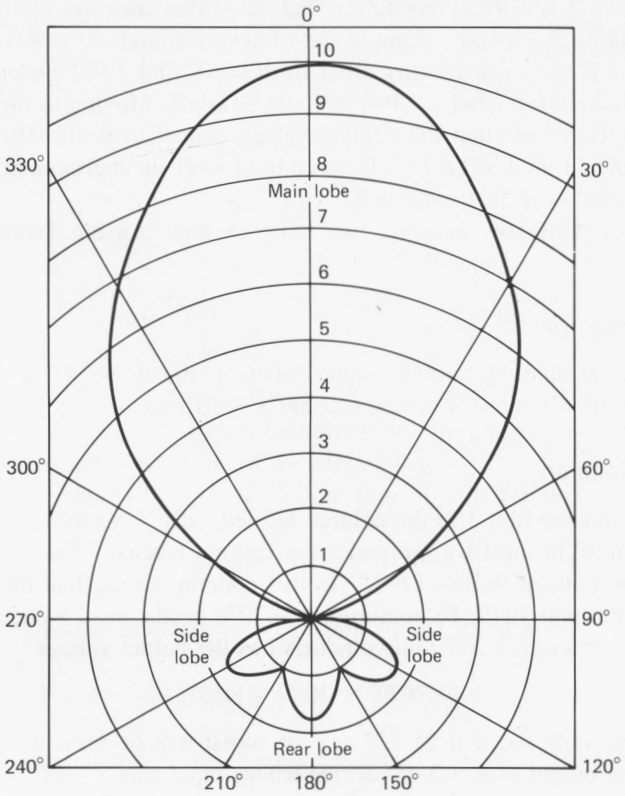


Fig. 3-21. Antenna radiation pattern parts.

Some of the terms associated with antennas are:

1. *Antenna gain*—the increase in signal level over that of a reference antenna expressed in decibels. The reference antenna most commonly used is the *folded-dipole* antenna. The construction of this antenna is shown in the Appendix.
2. *Side-lobe level*—the amount of signal in a side lobe compared to that in the main lobe.
3. *Front-to-back ratio*—the ratio of power gain between the front or main lobe and the rear lobe of an antenna in decibels.
4. *Half-power beam width*—the points on the main lobe that represent half of the power level of the main lobe.
5. *Horizontal beam width*—the width of the horizontal radiation from an antenna. The beam width is measured in degrees from the point of origin.
6. *Vertical beam width*—the width of the vertical radiation from an antenna. The beam width is measured in degrees from the point of origin.
7. *Impedance*—the total opposition offered to a signal by

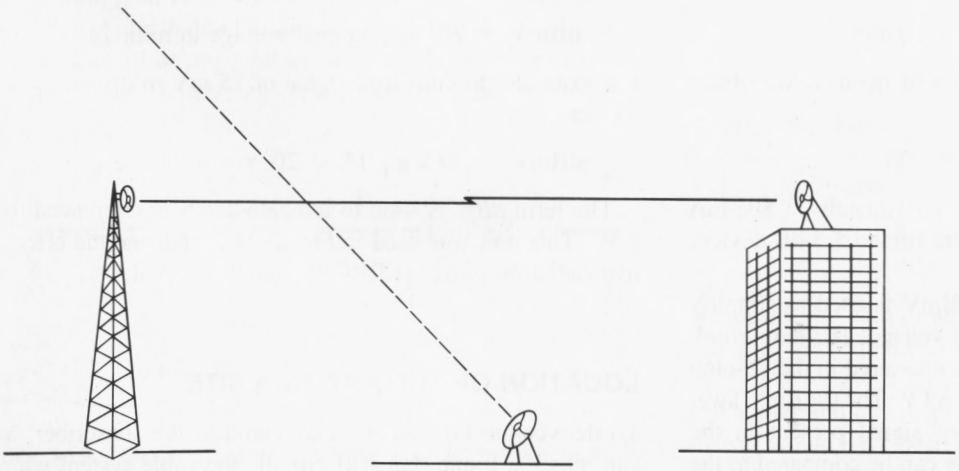


Fig. 3-20. Interference from nearby microwave transmitters.

the antenna. Impedance is measured in ohms and represented by the symbol *Z*. Antennas used in CATV have 75 Ω of impedance.

8. *Voltage standing-wave ratio*—the ratio of the amplitude of the electric field at a voltage maximum to that at an adjacent voltage minimum. The voltage standing-wave ratio (VSWR) is a measure of the quality of match between the antenna and the transmission line. A VSWR of 1.5 or less is considered acceptable.
9. *Bandwidth*—the range of frequencies over which an antenna will operate efficiently.
10. *Beam angle*—the angle between the axis of a radiated signal and the point at which the signal level drops to one-half the value at the axis.
11. *Signal-to-noise ratio*—the ratio of the magnitude of the signal to that of the noise present along with the signal. The signal-to-noise ratio is generally expressed in decibels.

The input signal from an antenna must be relatively constant. If the level is too high, it is reduced, but if it is too low, it must be increased in value. This is accomplished by amplifying the signal through a preamplifier. An antenna preamplifier is mounted on the antenna mast of each antenna requiring one and should (1) be designed for the channel on which the antenna is operating, (2) not introduce much noise to the signal, (3) have high gain, and (4) be rugged and waterproof.

Some more common types of receiving antennas used in CATV are the yagi antenna, the log-periodic antenna, the corner reflector, and the parabolic reflector.

Yagi Antenna

A *yagi* antenna is a dipole antenna with two or more additional elements. The construction and radiation pattern of a yagi antenna are shown in Figs. 3-22 and 3-23. In our study of the dipole antenna we saw that the radiated energy went both forward and backward. This is a disadvantage because half of the energy goes in the wrong direction. To eliminate this omnidirectional characteristic, experimenters placed a slightly longer conductor ¼ wavelength behind the driven element and found that it improved the gain of the antenna by about 5 dB in the forward direction. They called this element the *reflector*. They also placed a slightly shorter conductor one-quarter wavelength in front of the driven element and noticed that the directional characteristic of the antenna was improved. The present yagi antenna has the reflector 0.15 λ in back of the driven element and the director 0.10 λ in front of it. When additional directors are added, antennas can be made with exceptional directivity. Most yagi antennas used in CATV are constructed to operate at one frequency. The overall gain of a three-element yagi antenna approaches 6 to 7 dB. Yagi antennas are used for the reception of the VHF TV channels (Channels 2 to 13). The VHF frequencies extend from 30 to 300 mHz.

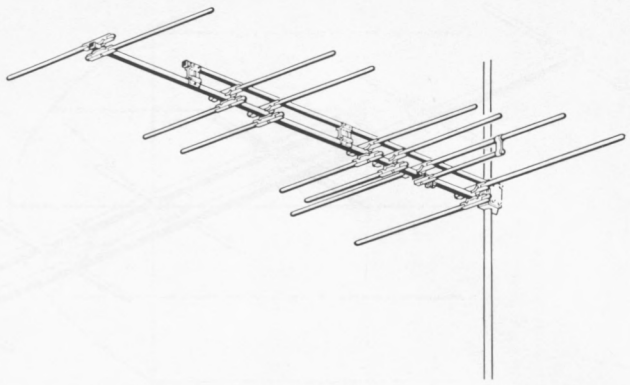


Fig. 3-22. Yagi antenna. *(Winegard Co.)*

Specifications for a typical five-element yagi antenna are:

Electrical	
Impedance	75 Ω
Gain (over a reference antenna)	10.61 dB
VSWR	1.32
Horizontal beam width	58°
Vertical beam width	73°
Front-to-back ratio	16 dB
Mechanical	
Crossarm	1⅜ in. square tubing
Elements	⅝ in. OD tubing
U bolt	⅜ in. OD × 3 in. galvanized steel

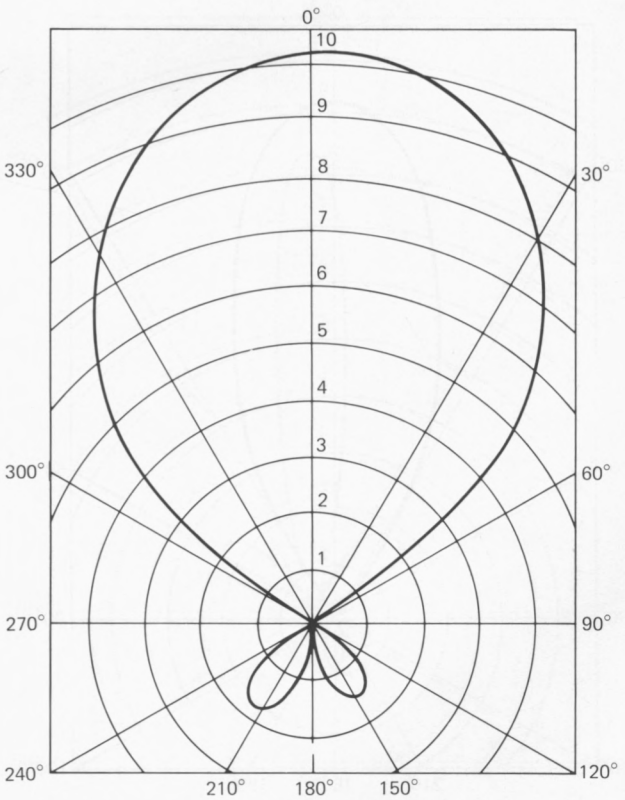


Fig. 3-23. Yagi antenna radiation pattern.

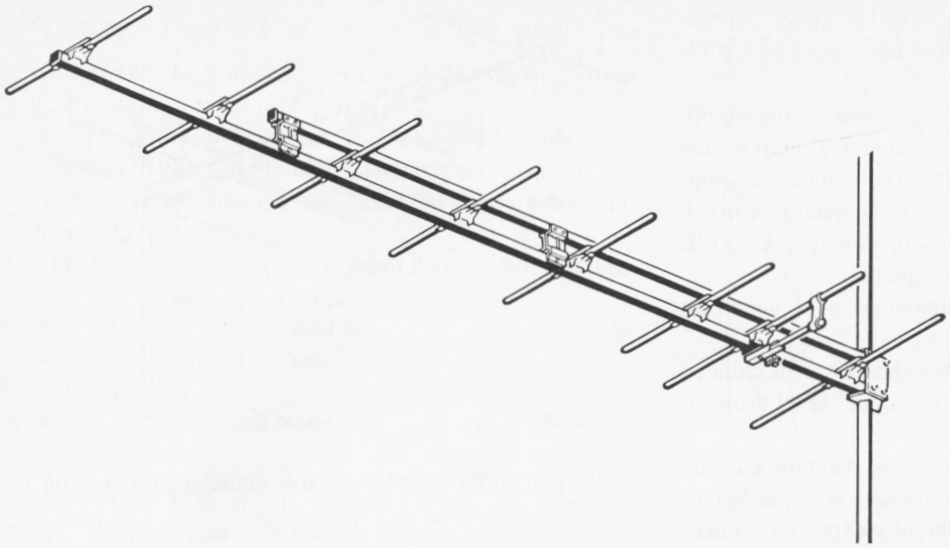


Fig. 3-24. Log periodic antenna. *(Winegard Co.)*

Log-Periodic Antenna

This type of antenna is one of a class of frequency-independent antennas. A frequency-independent antenna is one that will operate over a wide range of frequencies. Most of the older types of antennas operated at a fixed frequency dictated by their physical lengths. The log-periodic antenna is constructed in such a way that the elements and their spacing have dimensions that increase logarithmically from one end of the antenna to the other so that the ratio of element length to spacing remains constant. Figure 3-24 shows a log-periodic antenna. Log-periodic antennas are used to cover a number of stations that lie in the same geographic direction. The individual signals are separated as they enter the head-end by either a filter network or a mixer. A typical log-periodic antenna pattern is shown in Fig. 3-25. Log-periodic antennas are used to receive a small band of VHF TV channels.

Specifications for a typical log-periodic antenna are:

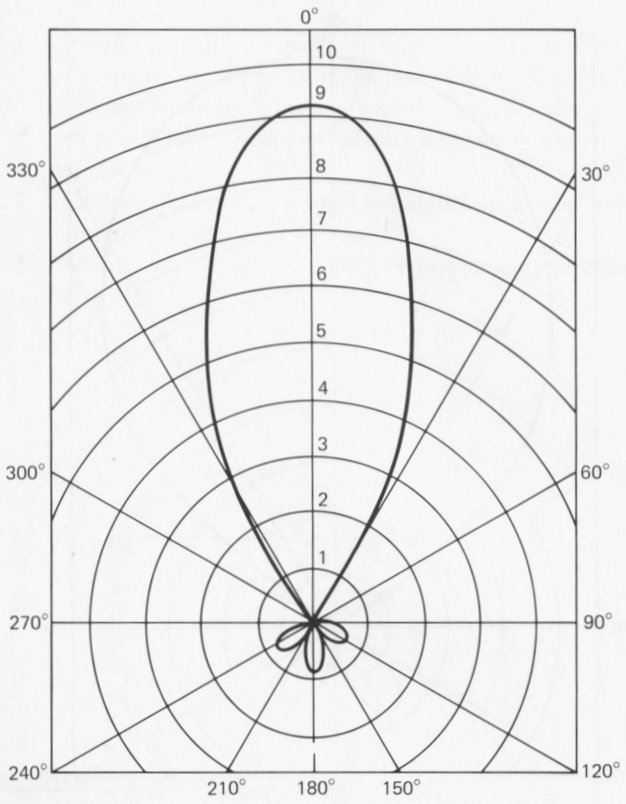


Fig. 3-25. Log periodic antenna radiation pattern.

Electrical	
Impedance	75 Ω
VSWR	1.38
High-band gain*	12.7 dB
Low-band gain*	9.6 dB
FM gain*	6.3 dB
VHF gain*	11.8 dB

*Gain over a reference antenna.

Mechanical	
Crossarm	1⅝-in. sq. tubing
Elements	½-in.-OD tubing
U bolt	⅝ in. OD × 3½ in. galvanized steel

Corner Reflector

The corner reflector is a simple one-half-wavelength dipole antenna that is mounted one-quarter wavelength from the intersection of two sheets of grid material. The two sheets of grid material, mounted at a 90° angle, act as a reflector and direct the electromagnetic energy toward the dipole. The grid material is one and one-half wavelength high and two to three wavelengths wide. The corner reflector is best suited for use as a UHF antenna (Channels 14 to 83) be-

cause of physical size. A corner reflector antenna is shown in Fig. 3-26. The UHF frequencies extend from 300 to 3000 Mhz.

Parabolic Reflector (Dish Antenna)

The parabolic antenna is designed to radiate extremely high frequencies called *microwaves* and to concentrate them into narrow beams of energy. The frequency range of microwaves is approximately 1000 to 100,000 MHz. In Fig. 3-9 we can see that radiated energy builds up and falls, giving us what is termed a *spherical wave*. A spherical wave is a wave in which the wave fronts have the same center. A spherical wave front spreads out as it travels, producing a pattern that is not too sharp or directive. On the other hand, a plane wave front does not spread out because all of the waves move forward in the same direction. For a sharply defined beam, the need exists to change the spherical wave front from the antenna into a plane wave front. A parabolic reflector is one means of accomplishing this.

Radio waves behave similarly to light waves. Microwaves travel in straight lines, as do light rays, and may be focused or reflected just as light rays can. In Fig. 3-27, an antenna is placed at the focal point F of a parabolic reflector. The field leaving this antenna has a spherical wave front. As each part of the wave front reaches the reflecting surface, it is shifted 180° in phase and sent outward at angles that cause all parts of the field to travel in parallel paths. Because of the shape of a parabolic surface, all paths from F to the reflector and back to line XY are of the same length. Therefore, all parts of the field arrive at line XY at the same time after being reflected.

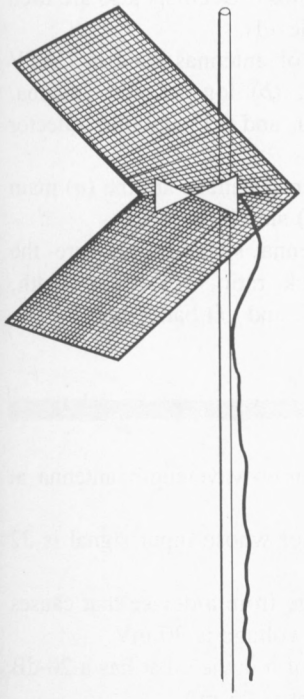


Fig. 3-26. Corner reflector.

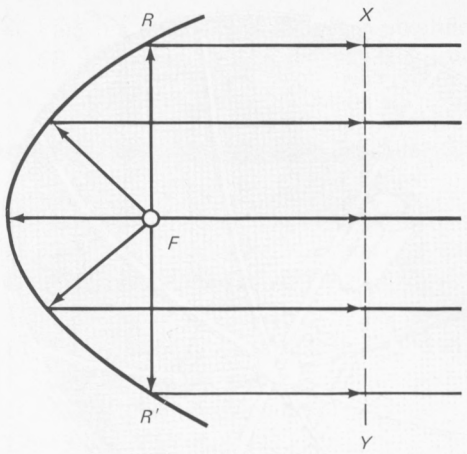


Fig. 3-27. Parabolic reflector radiation.

If a dipole is used as the source of radiation, there will be radiation from the antenna into space as well as toward the reflector. To prevent this occurrence, a hemispherical shield (not shown) is used to direct this radiation toward the reflective surface. By this means, direct radiation is eliminated, the beam is sharpened, and all the power is concentrated in the beam. Without the shield, some of the radiated field would leave the radiator directly. Since it would not be reflected, it would not become a part of the main beam and thus could serve no useful purpose.

The radiation from this antenna contains a major lobe, which is directed along its axis, and several minor lobes, as shown in Fig. 3-28. Very narrow beams are possible

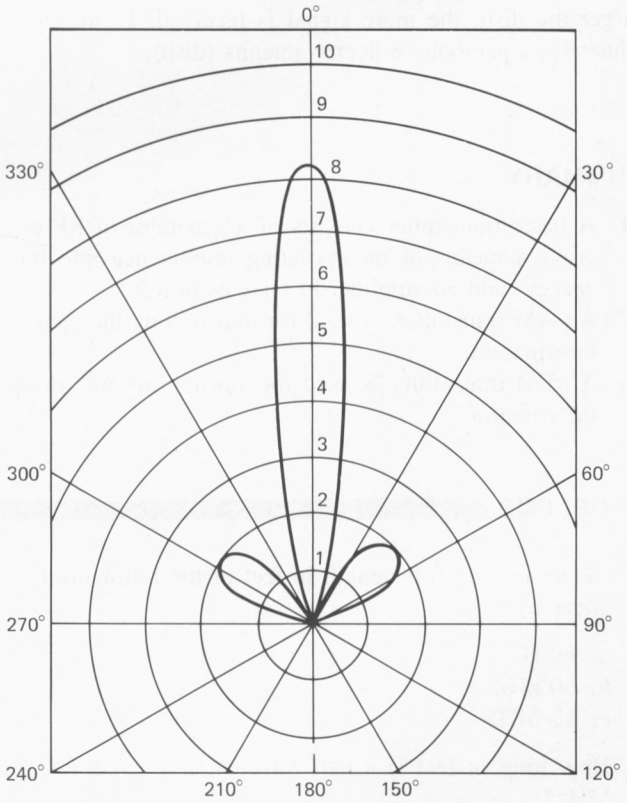


Fig. 3-28. Parabolic reflector radiation pattern.

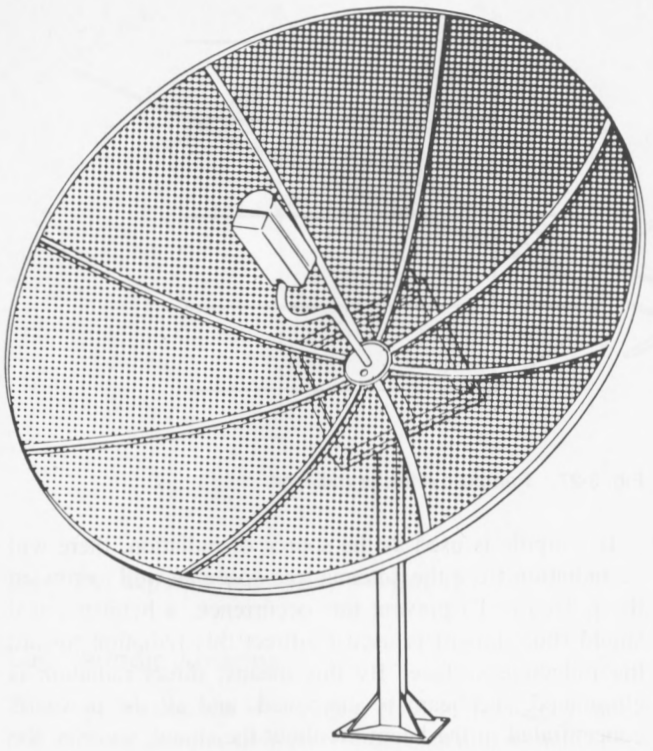


Fig. 3-29. Parabolic reflector receiving antenna. *(Winegard Co.)*

with this type of reflector. For reception of the satellite signal, the opposite occurs. All the energy received from the satellite strikes the reflector and is focused on the dipole antenna. This highlights the advantage of a large dish. The larger the dish, the more signal is received. Figure 3-29 illustrates a parabolic reflector antenna (dish).

SUMMARY

1. A basic transmitter consists of a generator of RF energy, a means of incorporating intelligence into this energy, and an amplifier to raise its power.
2. An AM transmitter is used for transmitting the picture information.
3. An FM transmitter is used for transmitting the sound information.
4. A diplexer is used to enable both the picture and sound signals to be radiated from the same antenna.
5. An antenna is a conductor used for radiating electromagnetic waves into, or receiving electromagnetic waves from, space.
6. The wavelength of an electromagnetic wave may be found by the following formula:

   Wavelength (feet) = 984/MHz or 984,000/kHz

7. The dipole antenna is one of the most popular antennas used for transmission and reception of electromagnetic (radio) waves.
8. For maximum efficiency, the two conductors (elements) of the dipole antenna should be one-quarter wavelength each.
9. The ground wave of an antenna is that part of a radio wave that travels along the surface of the earth.
10. The sky wave of an antenna is that part of a radio wave that travels into the ionosphere and is reflected back to the earth's surface.
11. The critical angle of a radio wave is that angle that allows the wave to be reflected back to earth without passing through the ionosphere.
12. The critical frequency is the highest frequency that can be sent upward and still be reflected back to earth.
13. A skip zone is an area on the earth that is devoid of signal. The skip zone is located between where the ground wave ends and the sky wave can be received.
14. Fading occurs when a received signal varies in intensity over a short period of time. Fading may be caused by the same signal arriving out of phase or the sky wave moving as a result of changes in the ionosphere.
15. Decibels are the standard unit for expressing transmission and reception gain or loss. Decibels also are used to express relative power levels.
16. The more common types of antennas used in CATV are the (*a*) yagi antenna, (*b*) log-periodic antenna, (*c*) corner reflector antenna, and (*d*) parabolic reflector antenna.
17. The major parts of an antenna pattern are the (*a*) main lobe, (*b*) rear lobe, and (*c*) side lobes.
18. The most important antenna specifications are the (*a*) gain, (*b*) front-to-back ratio, (*c*) beam width, (*d*) impedance, (*e*) VSWR, and (*f*) bandwidth.

PROBLEMS

1. Determine the wavelength in feet of the following frequencies:
   - ***a.*** 60 Hz
   - ***b.*** 60 kHz
   - ***c.*** 12 MHz
2. How long in feet is a half-wavelength antenna for 25 MHz?
3. How long in feet is a quarter-wavelength antenna at 120 Hz?
4. Find the gain of an amplifier whose input signal is 32 mW and output is 2 W.
5. Determine the output voltage from a device that causes a 7-dB loss when the input voltage is 30 mV.
6. Calculate the input current of a device that has a 20-dB gain when the output current is 25 mA.

7. Determine the input voltage from a device that has a 4-dB loss when the output voltage is 4 mV.
8. Find the output signal from an amplifier that has a 30-dB gain when the input signal is 7 mW.

REVIEW QUESTIONS

1. Name the two types of transmitters discussed in this chapter.
2. What type of transmitter is used to process the sound signal?
3. What is the purpose of the diplexer?
4. Describe how an antenna radiates electromagnetic (radio) waves.
5. Define wave propagation.
6. Describe a ground wave.
7. Describe a sky wave.
8. Which travels further, the ground wave or the sky wave? Why?
9. Name three layers of the ionosphere.
10. Describe multiple-hop transmission.
11. What is temperature inversion?
12. What is the duct effect?
13. What is the decibel formula for power?
14. Name three types of antennas used in CATV.
15. Define antenna gain.
16. Define front-to-back ratio.
17. Define VSWR.
18. What is the impedance of the antennas used in CATV?
19. What is meant by an antenna being frequency-independent?
20. What is a spherical wave front?
21. Name three factors in the selection of an antenna site.

4
CHAPTER
THE CATV HEAD-END

INTRODUCTION

In this chapter you will learn about:

1. Co-channel and adjacent-channel interference from commercial TV stations
2. The various types of electronic equipment used to process the signals that are placed on the "cable"
3. TV system fundamentals
4. TV signals
5. TV camera pickup tubes and devices
6. The basic principles of operation of a TV receiver

The head-end is that portion of the CATV system that accepts (1) programs of local origination, (2) signals from local commercial radio and TV stations, and (3) satellite signals from other sources in this country or from other parts of the world and separates, processes, amplifies, and assigns them to new channels on the cable distribution system. Figure 1-4 shows the relationship of the various parts of the CATV system.

CO-CHANNEL AND ADJACENT-CHANNEL INTERFERENCE

The term *co-channel* refers to two TV stations on the same channel, while the term *adjacent channel* refers to two TV stations on channels next to each other. In Fig. 4-1 we can see that TV channels are 6 MHz wide and follow each other. The only exceptions to this are Channels 4 and 5, which have 4 MHz separating them, and Channels 6 and 7, which are separated by the FM radio band. Therefore, Channels 4 and 5, and 6 and 7, are not considered adjacent channels. A break also exists between the VHF band (Channels 2 to 13) and the UHF band (Channels 14 to 83).

To minimize the effects of co-channel and adjacent-channel interference, the Federal Communication Commission maintains sufficient separation between TV stations.

These separations are satisfactory for the average viewer receiving off-the-air signals, but cable systems, with their tall towers and high-gain antennas, are subject to considerable co-channel and adjacent-channel interference.

Co-Channel Interference

The visual effects of another TV station operating on the same channel as the desired station may be the presence of either ghosts, dual images, or dark lines in the picture. These lines may be either stationary or moving up and down the picture. A "ghost" is a duplicate image, weaker than the main image, that appears to the side of the main image on the TV screen. Figure 4-2 shows how a ghost might result when a portion of the signal is reflected and arrives later than the main signal. A dual image is the presence of two different pictures on the TV screen at the same time.

Adjacent-Channel Interference

To understand adjacent-channel interference, we should look at Fig. 4-3. In this figure we can see that the lower-channels sound carrier is located 1.5 MHz below the picture carrier of the desired channel and the upper-channel picture carrier is located 1.5 MHz above the sound carrier of the desired channel. Adjacent-channel interference then is the interaction between the picture carrier of one channel and the sound carrier of an adjacent channel. One form of interference resulting from the interaction of adjacent-channel carriers is known as the "windshield-wiper effect." This type of interference is seen as a line slowly moving across the TV receiver screen.

HARMONICALLY AND INCREMENTALLY RELATED CARRIER CHANNEL SPACINGS

Another form of interference found in cable systems is known as *triple beat*. Triple beats are generated by a combination of three carrier frequencies that together create a resultant frequency. When this resultant frequency falls within the video portion of another channel, it causes distortion in the picture of that channel.

As an example, let us find the frequency that would result from the addition of the picture carriers of Channels 2, 3, and 4. Using Fig. 4-1, we find that these are

$$55.25 + 61.25 + 67.25 = 183.75 \text{ MHz}$$

The frequency of 183.75 MHz falls within the picture portion of Channel 8 (180 to 186 MHz).

In an attempt to alleviate the problems created by triple beats, some cable systems have employed either harmonically related (HRC) or incrementally related carriers (IRC) systems for channel spacings. In the HRC system, all standard

Channel Number	*Frequency Range (MHz)*	*Picture Carrier (MHz)*	*Sound Carrier (MHz)*	*Channel Number*	*Frequency Range (MHz)*	*Picture Carrier (MHz)*	*Sound Carrier (MHz)*
2	54–60	55.25	59.75	43	644–650	645.25	649.75
3	60–66	61.25	65.75	44	650–656	651.25	655.75
4	66–72	67.25	71.75	45	656–662	657.25	661.75
5	76–82	77.25	81.75	46	662–668	663.25	667.75
6	82–88	83.25	87.75	47	668–674	669.25	673.75
7	174–180	175.25	179.75	48	674–680	675.25	679.75
8	180–186	181.25	185.75	49	680–686	681.25	685.75
9	186–192	187.25	191.75	50	686–692	687.25	691.75
10	192–198	193.25	197.75	51	692–698	693.25	697.75
11	198–204	199.25	203.75	52	698–704	699.25	703.75
12	204–210	205.25	209.75	53	704–710	705.25	709.75
13	210–216	211.25	215.75	54	710–716	711.25	715.75
14	470–476	471.25	475.75	55	716–722	717.25	721.75
15	476–482	477.25	481.75	56	722–728	723.25	727.75
16	482–488	483.25	487.75	57	728–734	729.25	733.75
17	488–494	489.25	493.75	58	734–740	735.25	739.75
18	494–500	495.25	499.75	59	740–746	741.25	745.75
19	500–506	501.25	505.75	60	746–752	747.25	751.75
20	506–512	507.25	511.75	61	752–758	753.25	757.75
21	512–518	513.25	517.75	62	758–764	759.25	763.75
22	518–524	519.25	523.75	63	764–770	765.25	769.75
23	524–530	525.25	529.75	64	770–776	771.25	775.75
24	530–536	531.25	535.75	65	776–782	777.25	781.75
25	536–542	537.25	541.75	66	782–788	783.25	787.75
26	542–548	543.25	547.75	67	788–794	789.25	793.75
27	548–554	549.25	553.75	68	794–800	795.25	799.75
28	554–560	555.25	559.75	69	800–806	801.25	805.75
29	560–566	561.25	565.75	70	806–812	807.25	811.75
30	566–572	567.25	571.75	71	812–818	813.25	817.75
31	572–578	573.25	577.75	72	818–824	819.25	823.75
32	578–584	579.25	583.75	73	824–830	825.25	829.75
33	584–590	585.25	589.75	74	830–836	831.25	835.75
34	590–596	591.25	595.75	75	836–842	837.25	841.75
35	596–602	597.25	601.75	76	842–848	843.25	847.75
36	602–608	603.25	607.75	77	848–854	849.25	853.75
37	608–614	609.25	613.75	78	854–860	855.25	859.75
38	614–620	615.25	619.75	79	860–866	861.25	865.75
39	620–626	621.25	625.75	80	866–872	867.25	871.75
40	626–632	627.25	631.75	81	872–878	873.25	877.75
41	632–638	633.25	637.75	82	878–884	879.25	883.75
42	638–644	639.25	643.75	83	884–890	885.25	889.75

Fig. 4-1. Commercial TV channel frequencies.

cable channels are assigned even frequencies that are 6 MHz apart. In the IRC system, cable Channels 5 and 6 are increased in frequency by 2 MHz.

In both the HRC and IRC systems of channel spacing, a new channel is created between Channels 4 and 5. Table 4-1 compares the standard cable channel frequencies with the HRC and IRC channel frequencies.

In our previous example, use of the HRC system would result in a carrier at 180 MHz (54 + 60 + 66), which would not interfere with the picture on Channel 8.

Although improvements in picture quality result from the use of HRC and IRC, the cable industry is reluctant to use these systems because of Federal Communications Commission (FCC) requirements concerning the use of restricted frequencies. In some instances certain cable channels interfered with aeronautical frequencies when HRC and IRC systems were used, and those channels could not be utilized.

HEAD-END EQUIPMENT

At the head-end of a cable system, the signals from the local radio and TV stations, as well as those from earth satellites and local origination, are processed and placed on the coaxial cable for distribution to the subscriber. As they enter and pass through the head-end, these signals undergo the following modifications:

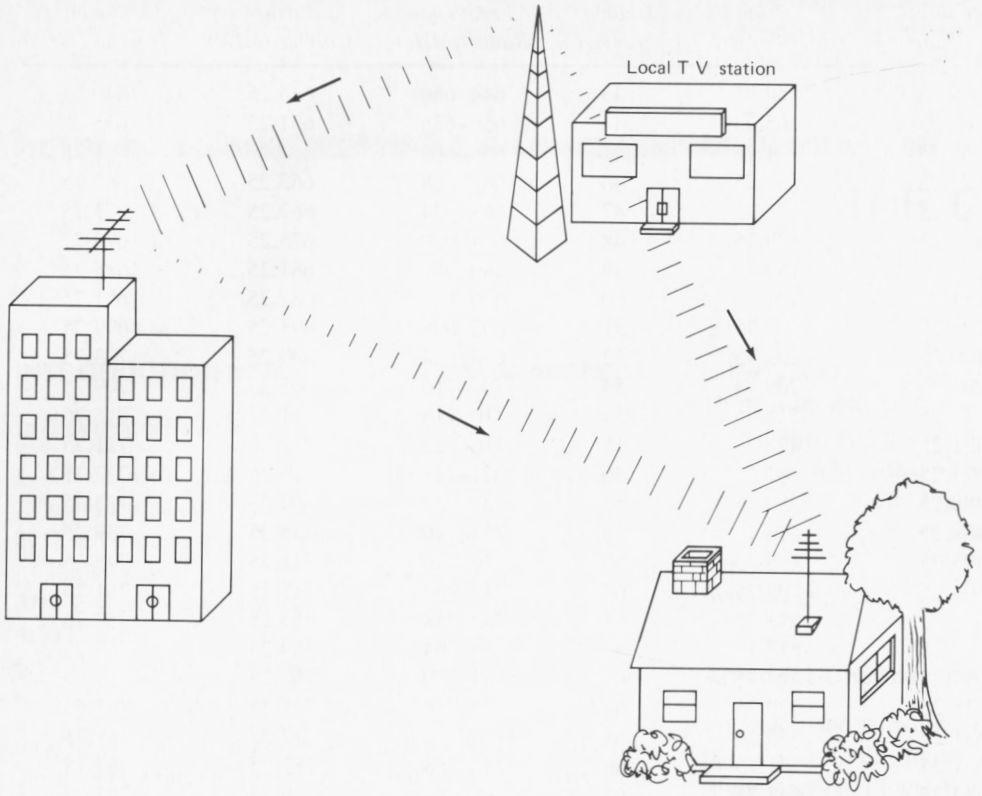


Fig. 4-2. The production of TV ghost images.

1. *Amplification*. The input signals to the head-end should be at a level close to the required input values for the processing equipment. If they are too low, they must be increased in value. This is accomplished by amplifying the signal by means of a preamplifier.
2. *Signal filtering*. To obtain the desired signal without any adjacent channel interference, band-pass filters are employed. These filters are located within the processing equipment itself.
3. *Separation of signals*. When an antenna is used to receive two or more stations, a means of separating them is needed. After separation, the individual signals are sent to their respective pieces of equipment.

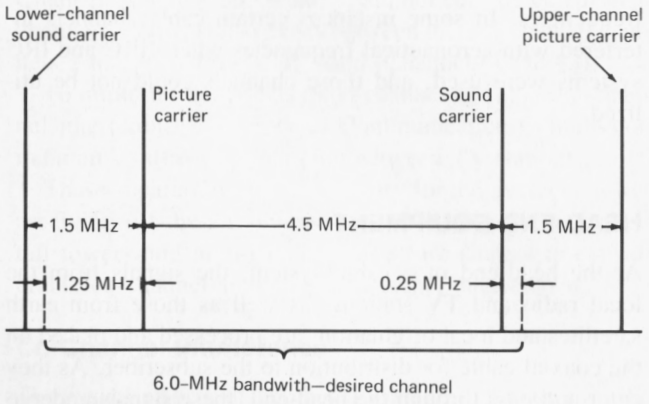


Fig. 4-3. Relationship of adjacent channel picture and sound carriers.

4. *Automatic gain control*. Because of fading of received signals, provisions are made to automatically maintain the level of each incoming signal. This is achieved with the use of automatic gain control (AGC) circuitry.
5. *Conversion to another channel*. The need to convert a signal from one frequency to another becomes necessary whenever the frequency of a signal is above the frequency limits of the cable system or a cable channel is operating at the same frequency as that of a local TV station. Because the highest frequency used in a CATV system is either 300 or 450 MHz (depending on the system), any signal above these limits must first be down-converted (reduced in frequency) to a VHF channel before being sent to the distribution system. To prevent the simultaneous reception of both a CATV signal and a commercial TV signal, the signal on the cable is converted to a cable channel above or below the "off-air" signal. If both signals were received simultaneously in the CATV subscriber's TV set, ghosting would result because of co-channel interference.
6. *Adjustment of output signal levels*. Because many different types of signals are processed by the head-end, individual signal adjustments are made so that all the signals sent to the distribution system are at a uniform level.
7. *Combination of signals*. Regardless of the number or types of signals processed by the head-end, a method of combining them is needed. Signals are combined for

TABLE 4-1. Comparison of Standard to HRC and IRC TV Channel Frequencies

CATV Channel	Standard		HRC		IRC	
	Picture	Sound	Picture	Sound	Picture	Sound
2	55.25	59.75	54.00	58.50	55.25	59.75
3	61.25	65.75	60.00	64.50	61.25	65.75
4	67.25	71.75	66.00	70.50	67.25	71.75
—	—	—	72.00	76.50	73.25	77.75
5	77.25	81.75	78.00	82.50	79.25	83.75
6	83.25	87.75	84.00	88.50	85.25	89.75
7	175.25	179.75	174.00	178.50	175.25	179.75
8	181.25	185.75	180.00	184.50	181.25	185.75
9	187.25	191.75	186.00	190.50	187.25	191.75
10	193.25	197.75	192.00	196.50	193.25	197.75
11	199.25	203.75	198.00	202.50	199.25	203.75
12	205.25	209.75	204.00	208.50	205.25	209.75
13	211.25	215.75	210.00	214.50	211.25	215.75

placement on a common cable and then distributed to CATV subscribers. Combining systems are generally designed so that the level of the signal leaving the head-end is the same as that of the distribution system amplifiers, typically 32 dBmV.

The types of equipment found in head-end installations and their functions are as follows:

1. *Video receiver*—will down-convert (reduce in frequency) the satellite signals to those used in the cable system. The two types of video receivers are (*a*) *fixed*—is crystal-controlled and responds to only one frequency and (*b*) *agile*—is tunable to any of the satellite transponders just as a radio can be tuned to a particular station.
2. *Modulator*—takes the video and audio signals from the video receiver and assigns them a carrier (RF) frequency corresponding to the channel to which this program has been assigned.
3. *Demodulator*—head-end equipment that recovers the information from a standard TV channel RF carrier. The outputs of the demodulator are the audio and video signals of the program.
4. *Processer*—takes a locally received TV or FM radio signal, filters it, and assigns it to a channel on the cable.
5. *Character generator*—places the words or symbols on the picture portion of the program. Examples of character-generated material might be the election results, weather alerts, or any other information that we see moving across the bottom of the screen of our TV sets.
6. *Video inserter*—an electronic device that places a prerecorded commercial announcement on the cable channel during a pause in the satellite program. This insertion is initiated by a signal called a *cuing* tone that is sent along with the satellite signal.
7. *Video tape player*—used to place a previously recorded program on a cable channel. Examples might be local sporting events, political speeches, news events, or locally produced programs.
8. *Receivers*—used to receive local weather reports, FM background music, and emergency civil defense reports.
9. *Standby power supply*—in event of power failure, will power the head-end equipment for up to 3 h under normal loading conditions.
10. *Pay channel encoder-decoder*—used to scramble or unscramble a pay channel to prevent those who have not contracted for this service from receiving it. One method of scrambling is accomplished by suppressing the pay channel synchronizing pulses (which are used to maintain a stable picture) so that they are hidden in the video information. The results of this suppression are diagonal lines and tearing of the picture.
11. *Multiple trunk distribution unit*—allows the output signals from the head-end to be fed into many trunk lines. On the individual lines, the trunk amplifiers can then control the signal according to its needs.
12. *Override controller*—installed in a cable system head-end to allow designated persons to interrupt programs during an emergency with either an audio message or text from a character generator.
13. *Pilot signal generator*—an unmodulated carrier that acts as a reference signal for the AGC circuits used in the distribution system amplifiers. In recent years the single pilot has given way to a dual pilot system in which an active high-frequency and an active low-frequency channel are used as pilot carriers. If the signal from one channel is lost, a standby carrier is supplied by the pilot signal generator.

TV SYSTEM FUNDAMENTALS

Television can be defined simply as the transmission and reception of visual images by means of electrical signals from one point to another. All TV methods are based on

the use of the following three basic elements: (1) a pickup device to convert an optical image into electrical signals, (2) a means of transmitting the electrical signal, and (3) a reproducing device to reconvert the electrical signal into an optical image.

Pickup devices include camera tubes such as the vidicon, as well as solid-state devices such as the metal oxide-semiconductor (MOS) image sensor. Transmitting devices include transmission lines, low- or high-power transmitters, satellites, and microwave relay stations. Generally, the reproducing device is a TV receiver, a TV monitor, or some form of projection system.

The first large-scale TV application was in commercial broadcasting. Technical requirements imposed on equipment used for commercial broadcasting are fairly well standardized by the Electronics Industries Association (EIA). The standardization is necessary because the objective of each TV station is the same: to produce a program suitable for transmission to home receivers. In the CATV industry, however, technical requirements vary widely from one application to another.

Another difference between commercial TV and CATV is that a greater variety of equipment and facilities are employed in CATV. Installations vary from a simple camera-monitor combination to highly complex combinations of cameras, distribution and switching equipment, and viewing monitors.

A basic TV system is shown in Fig. 4-4. An image of the scene is focused on the camera pickup tube. An electron beam in the tube scans the optical image and produces an electrical signal which varies in amplitude with the amount of light falling on each point in the image. A synchronizing signal (covered later) is added to the electrical picture signal from the camera, and the resultant signal is transmitted to the receiver.

Within the receiver, the synchronizing signal causes the electron beam in the picture tube to be in step with the scanning beam of the camera. The intensity of the beam is varied in accordance with the picture signal, and the image is made to appear on the face of the picture tube.

The time required for one vertical scan of the picture in broadcast TV systems in the United States is 1/60 s. The rate of 60 Hz was chosen because most commercial electrical power sources in the United States operate at a frequency of 60 Hz. Use of this frequency reduces the visible effects of some types of interference and simplifies the problem of synchronizing film projectors.

The number of scanning lines determines the maximum ability of the system to resolve fine detail (resolution). The present system of 525 lines was chosen for broadcast TV as the most suitable compromise between channel width and picture resolution. This number of lines has also been found satisfactory for CATV systems.

Interlaced scanning is used in both broadcast and CATV equipment. In the standard two-to-one method of interlacing, alternate lines are scanned consecutively from top to bottom. This principle is illustrated in Fig. 4-5, which shows interlaced scanning with 13 scanning lines. In this type of scanning, each group of alternate lines is called a "field," while the complete set of lines consisting of two consecutive fields, is called a "frame." Interlacing is accomplished by making the total number of lines in a frame an odd number. Thus the number of lines in each of the two fields is an even number plus a half. This results in consecutive fields which are displaced in space with respect to each other by half a line, thus producing interlacing of the lines. In both commercial broadcast TV and CATV, the total number of lines is 525, the total lines per field is 262½, the vertical scanning frequency is 60 Hz, the number of complete pictures (frames) per second is 30, and the horizontal scanning frequency is 15,750 Hz (60 × 262½).

TV SIGNALS

The standard TV video signal consists of three major elements: the picture information generated during active scanning time, picture blanking pulses, and the picture synchronizing pulses.

Picture Information

The picture information is a series of waves and pulses generated during active line scanning of the camera tube. As a scanning line moves across the face of the pickup tube, it is changed in amplitude in proportion to the brightness variations in the scene it is scanning. The amplitude variations are such that the maximum video amplitude produces black and the minimum video amplitude produces white. Ordinarily the maximum and minimum video am-

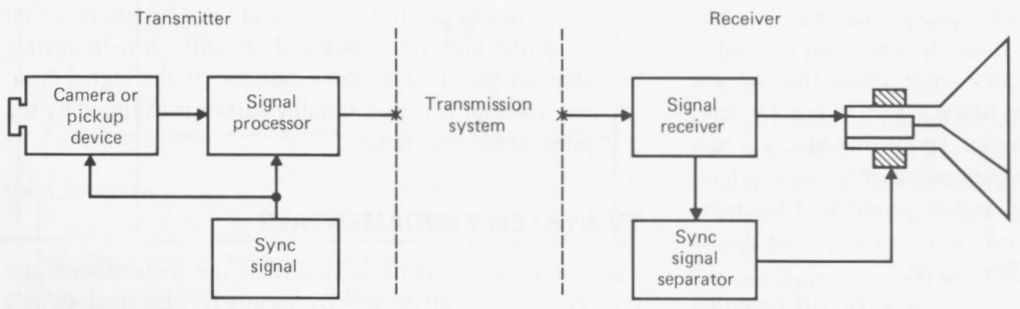


Fig. 4-4. Basic television system.

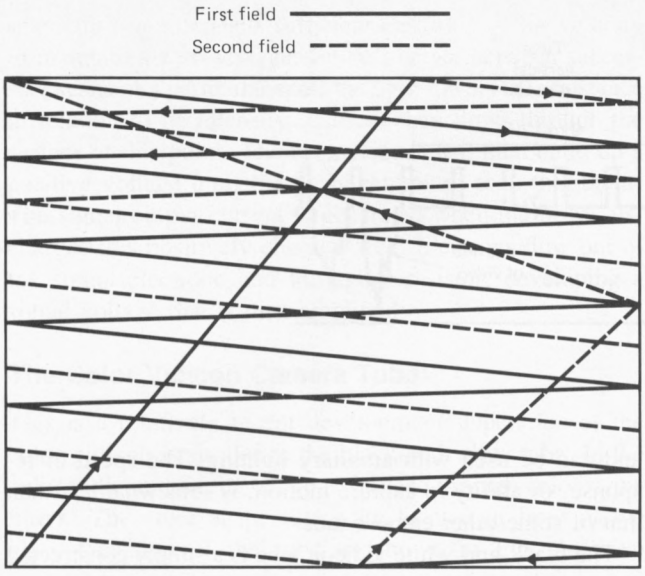


Fig. 4-5. Interlaced scanning.

plitude values represent 75 and 15 percent of the maximum carrier voltage, respectively, as can be seen in Fig. 4-6.

Picture Blanking Pulses

To prevent undesirable signals from entering the picture during retrace time (the time it takes for the scanning line to return to its starting point), blanking pulses are applied to the scanning beams in both the camera tube and the receiver picture tube. The camera's blanking pulses are used only in the camera tube and never appear in the final signal sent to the receiver. Blanking pulses for use of the receiver are inserted at the transmitter.

The function of the blanking pulses is to suppress the scanning beam in the picture tube during both vertical and horizontal retrace times. Blanking pulses are rectangular in shape. Their duration is longer than retrace pulses, therefore, they provide a clean, noise-free period during retrace. The complete video signal shown in Fig. 4-6 contains pulses for the horizontal retrace periods only. The horizontal pulses recur at intervals of 1/15,750 s. At the bottom of the picture they are replaced by vertical blanking pulses (shown in Fig. 4-7) which are similar to the horizontal pulses, except that they are of a much longer duration (approximately 15 scanning lines) and have a periodic recurrence of 1/60 s (60 Hz).

Synchronizing (Sync) Pulses

Synchronization of the scanning beams in the camera and the receiver must be exact at all times to provide a viewable picture. To accomplish this, synchronizing information is provided in the form of electrical pulses in the retrace intervals between successive lines and pictures as seen in Fig. 4-6. The retrace periods (which are as short as circuit considerations permit) are areas in which sync pulses may be inserted without interfering with the picture.

Synchronizing pulses are generated at the transmitter end of the TV system in the equipment that controls the timing of the scanning beam. They become a part of the complete signal, which is either transmitted to the receiver or is sent to the monitor. In this way, scanning operations in both ends of the TV system are always in step with each other.

Most TV systems produce synchronizing information which conforms to the basic requirements, although the degree of conformity varies widely. Figure 4-6 shows how the synchronizing signal is added to the picture information and the blanking signals to form a complete composite picture signal ready for transmission. Note that the duration of the horizontal sync pulse is considerably shorter than that of the blanking pulses. Vertical sync pulses are rectangular but of much shorter duration than the horizontal pulses.

To eliminate synchronization problems and maintain continuous horizontal synchronizing information throughout the vertical synchronization and blanking interval, another series of pulses called *equalizing pulses* are added. Equalizing pulses are shown in Fig. 4-7 before and after the sync pulses. The time between the last horizontal sync pulse and the first equalizing pulse changes from a full horizontal line interval to one-half of a horizontal line interval every other field. This is caused by the ratio between 15,750 and 60 Hz, which produces the necessary difference between fields to provide interlaced scanning. Since the horizontal circuits are adjusted to the frequency of the hor-

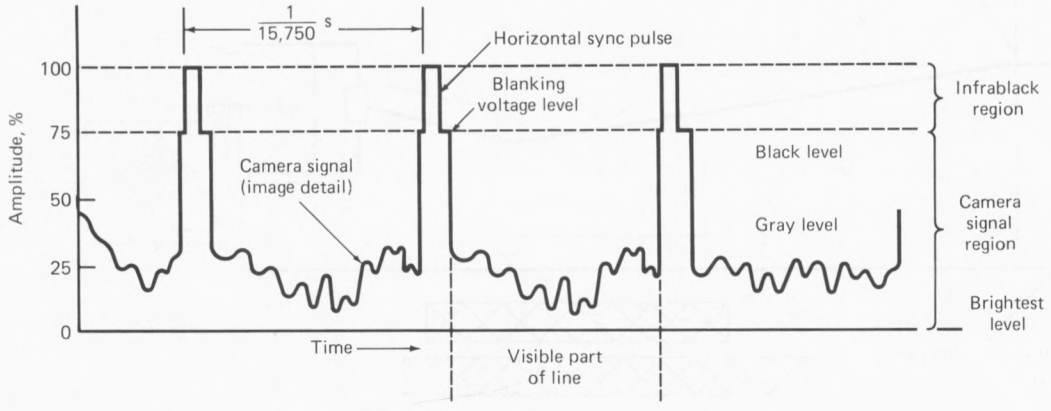


Fig. 4-6. The complete video signal for three scanned lines.

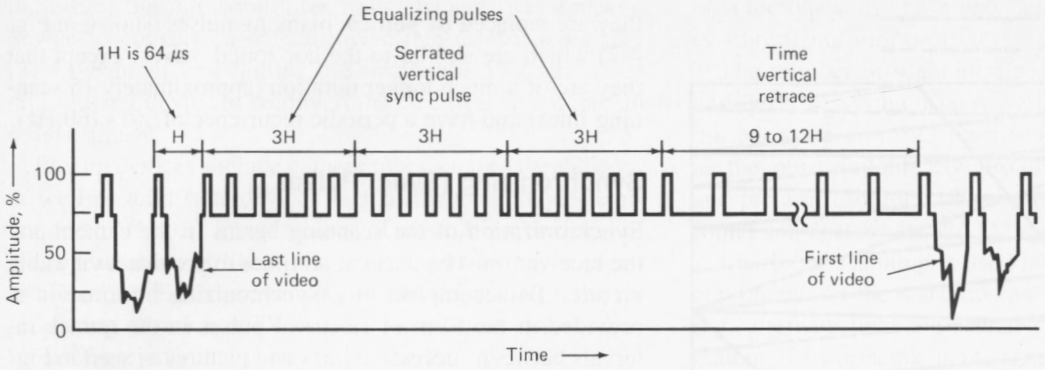


Fig. 4-7. Vertical synchronizing and equalizing pulses.

izontal sync pulses, it is triggered only by every other equalizing pulse.

TV PICKUP TUBES

A TV camera tube generates an electrical signal representing the light intensities present in the image focused on the tube. Each point of this image is scanned and an electrical voltage corresponding to the amount of light present is generated.

Television camera tubes are sensitive primarily to visible light. Recently some special tubes have been developed that are sensitive to light energy in the infrared and ultraviolet regions. Representative of camera tubes are the black-and-white and the color vidicon tubes.

Black-and-White Vidicon Camera Tube

This was originally developed for closed-circuit and industrial TV applications but was soon used in CATV studios. The name, however, is generally applied to a number of camera tubes employing an intrinsic photoconductive light-sensitive surface. Vidicon tubes have a moderate sensitivity and can be used with auxiliary lighting. The speed of response, or ability to capture motion, is somewhat less than that of some other camera tubes.

The black-and-white vidicon tube is a simply constructed storage type of camera tube as seen in Fig. 4-8. The output signal is developed by a low-velocity scanning beam originating in the cathode of the tube. The scanning beam begins at the top of the tube and is compelled to move from side to side as it is gradually moved downward. The movement of the scanning beam is caused by the deflection coils located at the top and bottom and on either side of the tube.

The target consists of a transparent signal electrode deposited on the faceplate of the tube. A thin layer of photoconductive material is then deposited over this electrode. The layer serves two purposes: (1) it is the light-sensitive element and (2) it forms the storage surface for the electrical charge that corresponds to the image.

The photoconductor has a high resistance when in the dark. Light falling on the photoconductive material excites electrons into a conducting state. This excitation lowers the resistance of the material at the point of illumination. A positive voltage is applied to one side of the photoconductive layer by the signal electrode. On the other side, the

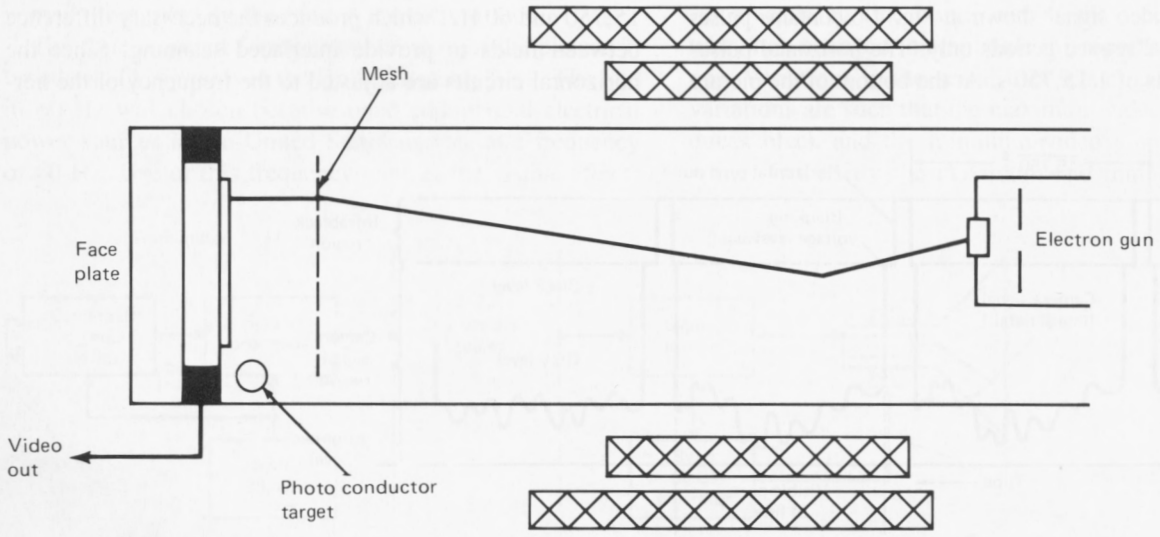


Fig. 4-8. Black-and-white vidicon camera tube.

scanning beam deposits sufficient electrons at low velocity to maintain a zero voltage. In the interval between successive scans of a particular spot, the light lowers the resistance in relation to its intensity. Current then flows through the surface at this point. The back surface will then build up a positive voltage until the beam returns to scan that point. The signal output current is generated when the beam discharges this positively charged area. Electrons flow out of the signal electrode and through a resistor, developing a signal voltage that is then amplified.

The Color Vidicon Camera Tube[1]

This is a relatively recent development. Operation of the color vidicon is similar to the black-and-white tube. In the color vidicon tube the image is focused through color stripe filters. The color stripe filters are located in front of the glass faceplate of the tube as shown in Fig. 4-9. An L-shaped area along one edge of the target surface and halfway across the bottom blocks light from reaching the target. The target current generated when the electron beam is scanned across this "optical black" area serves as a black-level reference.

Figure 4-10 is an enlarged close-up view of the striped filter target utilized in the vidicon tube. Located between the incoming light and the target surface are two diagonally placed striped filters. One of the filters is a cyan color, and the other is yellow. Spaces between the filters are transparent areas. It is the diagonal (striped) filters that allow this single tube camera system to develop the necessary color signals to provide color video signal development.

The cyan filter passes only blue- and green-light information through to the target surface. The red-light information is blocked out by the cyan filter. Conversely, the yellow filter passes only red and green light and blocks out the blue light. The transparent areas, or stripes, pass all three light colors—red, blue, and green. The areas covered by the overlap of the cyan and yellow filters pass only green light; the blue and red colors are blocked out. As can be seen, green light passes through all areas of the filter, and blue light and red light pass only through certain points. Development of the signal from the vidicon target can be explained by first examining the light passing through the striped filter as line *N* is scanned across the target.

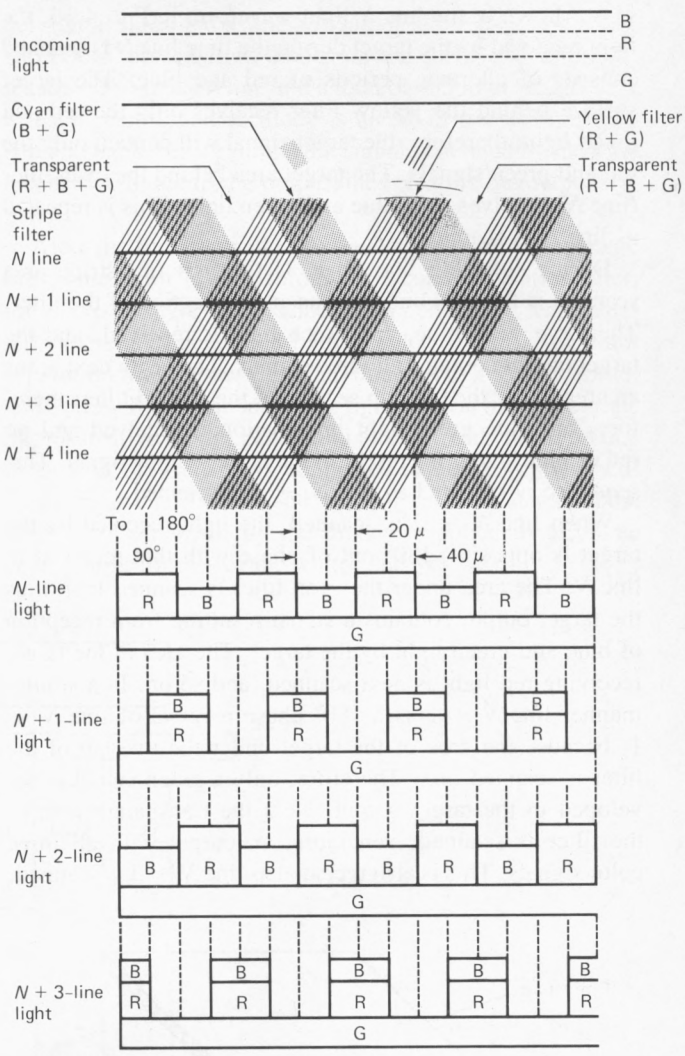


Fig. 4-10. Light characteristics of the striped filter vidicon. *(RCA Consumer Electronics)*

[1]Reproduced with permission of RCA Consumer Electronics

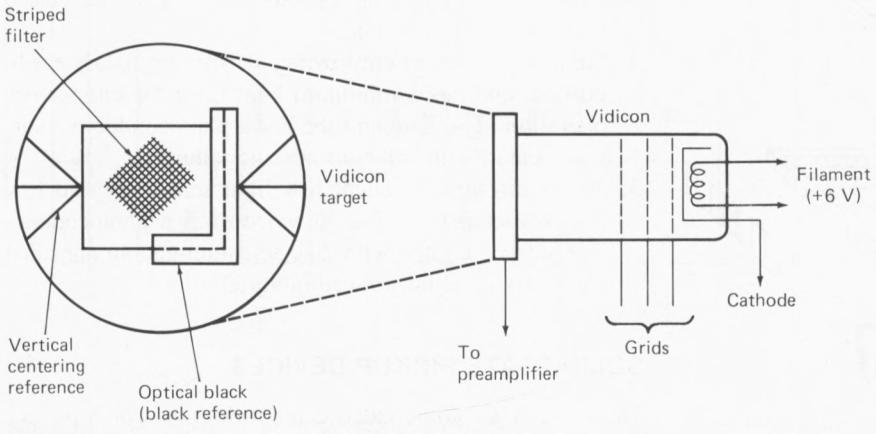


Fig. 4-9. Color vidicon camera tube. *(RCA Consumer Electronics)*

As shown in the line N light waveform in Fig. 4-10, the light received by the target during the time line N is scanned consists of alternate periods of red and blue. The target surface behind the yellow filter receives only the red and green light; therefore, the target signal will contain only the red and green signals. The target area behind the cyan filter (line N) receives only blue and green light. This is repeated as line N is scanned.

During scanning line $N + 1$, the first full stripe area scanned is the area under a transparent section of the filter. Therefore, red, blue, and green light is received, and the target output contains all three signals. The beam next scans an area under the overlap section of the striped filter; therefore, only the green-light information is received and no red or blue signal is present in the target output signal. This sequence is repeated as line $N + 1$ is scanned.

When line $N + 2$ is scanned, the light received by the target is opposite, 180° out of phase with that received in line N. The area under the cyan filter is scanned first; thus the target output contains a signal resulting from reception of blue and green light by the target. The area of the target receiving red light is next scanned, and so on. In a similar manner line $N + 3$ is a 180° phase reversal of line $N + 1$, because the area of the target under the overlap of the filter is scanned first. Therefore, only a green signal is developed in the target output. Next the transparent area of the filter is scanned, generating an output with all three color signals. This is also repeated as line $N + 3$ is scanned.

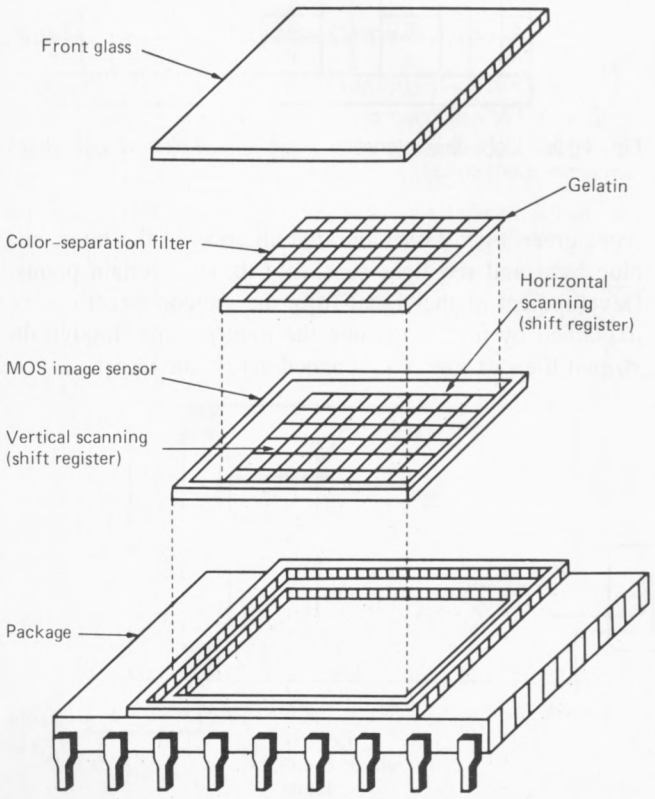


Fig. 4-11. Construction of a MOS image sensor. *(RCA Consumer Electronics)*

Line $N + 4$ is an exact repeat of line N; therefore, line $N + 5$ will be the same as line $N + 1$.

In comparing the four lines generated in the previous discussion, lines N, $N + 1$, $N + 2$, and $N + 3$, it can be seen that with each subsequent line the light received is delayed from the previous line by half the width of the striped filter. For instance, the red light on line N is received at T_0 or phase ϕ. The red light on line $N + 1$ is received at a delay equivalent to 90° or one-half the width of the filter stripe. On line $N + 2$, the red light is delayed another one-half of a stripe width from line $N + 1$ and the full width of a stripe from line N, therefore representing a phase shift of 180° or inverted. The red light on line $N + 3$ is also delayed an additional 90° from the light on $N + 2$ and by comparison to line $N + 1$, is 180° out of phase or inverted. This sequence is repeated as the beam is scanned horizontally and vertically across the target, thereby causing a 90° shift from line to line.

The signal shown in the diagram for lines N, $N + 1$, $N + 2$, and $N + 3$ represents the light falling on the target to generate a target current which is applied to a preamplifier circuit.

The brightness information generated by these filters is thus representative of the colors contained in the image. By electronic addition or subtraction of the signals produced by these filters, the color of the image can be determined. When the color signal is added to the overall brightness signal, an electrical equivalent of the complete color image is obtained.

Improved Camera Tubes

Two very important issues in pickup tube design are image lag characteristics and low light sensitivity. "Lag," or image retention, is the tendency for an image to remain after the object has moved. To reduce this lag tendency but increase low light sensitivity, manufacturers are producing photoconductive surfaces from different chemical compounds. The various tube designs and their characteristics are:

1. *Trinicon*—has slightly better color-resolution capabilities and lag characteristics than the vidicon. Like the vidicon, the trinicon has a photoconductive surface coated with antimony trisulfide.
2. *Saticon*—has excellent low lag sensitivity, is less easily burned, and has a minimum light level for satisfactory operation. The Saticon tube has a photoconductive surface coated with selenium arsenic tellurium.
3. *Newvicon*—has excellent low light sensitivity and low lag characteristics. The Newvicon has a photoconductive surface treated with zinc selenium and an annealed band of zinc tellurium-cadmium tellurium.

SOLID-STATE PICKUP DEVICES

There are other color video camera designs which do not use pickup tubes at all. Instead, a solid-state device converts

the light to video signals. Solid-state cameras use either a charge-coupled device (CCD) or MOS pickup system and are virtually free of lag. Figure 4-11 shows a MOS image sensor device. The MOS image sensor operates very similarly to the target surface of the vidicon tube. The only exception is, of course, that an electron beam is not used to scan the sensor surface. As is the case in tube-type pickup systems, the light received by the image sensor must first be divided into separate color groups to generate the correct signals. In the MOS image sensor construction, the color separation is created by a color separation filter made of a gelatin material between the cover glass and the sensor surface. The individual light sensing elements are located directly beneath the color separation filter. The signal generated by light falling on each sensor device is then scanned to generate the output signals.

As shown in Fig. 4-12, the sensing element of the MOS image sensor is made up of an array of photosensitive diodes located directly beneath the various segments of the color separation filter. The photosensitive diodes are arranged in horizontal lines across the surface of the device. There are 186,000 photosensitive diodes on the surface of the MOS sensor—384 in each line and a total of 485 lines. Connected to each photosensitive diode is an MOS transistor, which is responsible for "gating" the signal generated by the photosensitive diode to the output lines creating the output signals.

After the incoming light to the MOS sensor is separated into three color groups through the color separation filter, the photosensitive diode under each color filter section detects the signal generated by that color of light. The color separation filter passes light into three groups—cyan, white, and yellow light. The incoming light falls on the appropriate photosensitive diode, generating an electrical charge on that diode. As the transistors connected to the diodes are activated by the horizontal and vertical shift register circuits, the signal generated by the diode is applied to the three color output lines—cyan, white, and yellow.

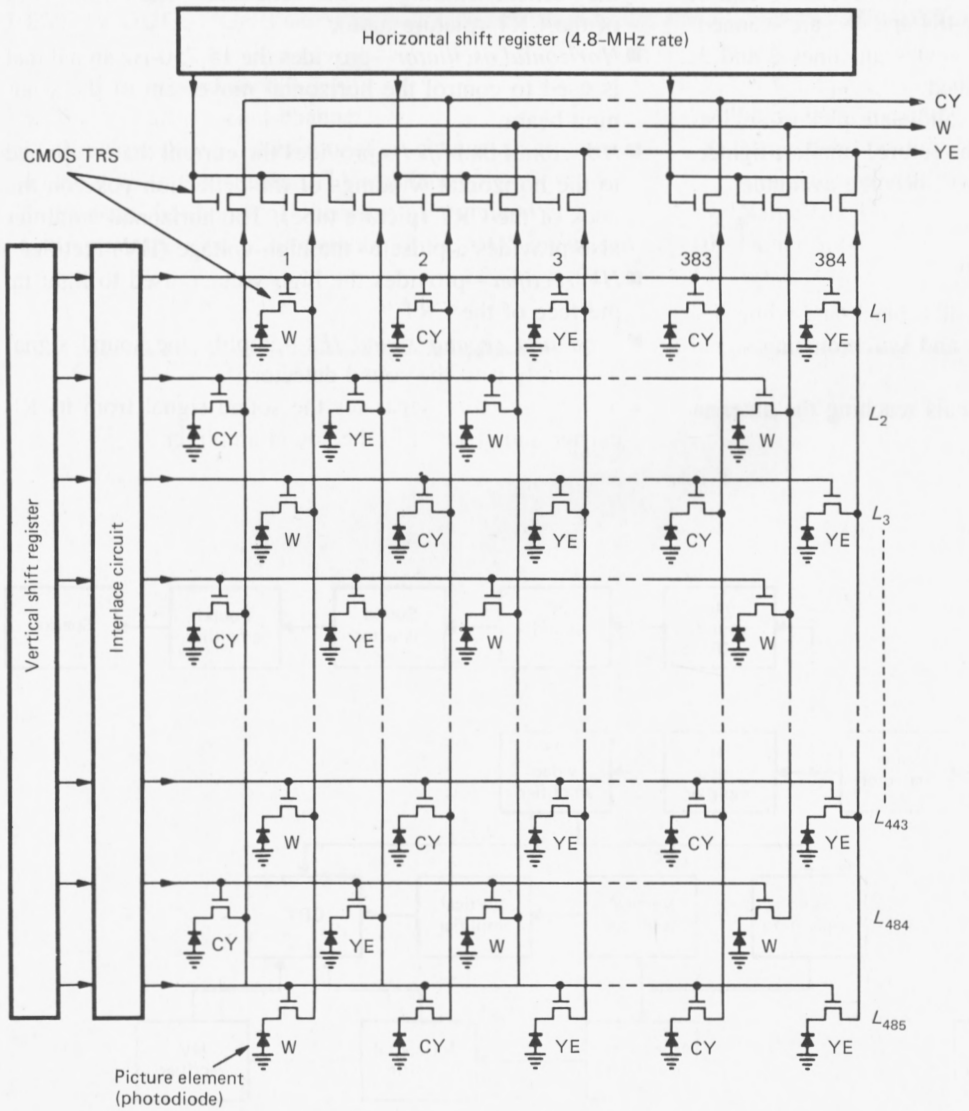


Fig. 4-12. Simplified image sensor signal generation. *(RCA Consumer Electronics)*

The vertical shift register determines which lines (in the vertical direction) are being scanned—line 1, line 2, and line 3, up through line 485. As can be seen by the arrangement of the three color groups, it is necessary to scan two lines simultaneously to generate the three output signals. At the beginning of a vertical field, the vertical shift register generates an output to activate the MOS transistors on lines 1 and 2; therefore, the signal from the photosensitive diodes is applied to the horizontal shift register MOS transistors. The horizontal shift register is driven by a 4.8-MHz clock and drives another group of MOS transistors (across the top). Each horizontal shift register pulse activates a group of three MOS transistors simultaneously—one for cyan, one for white, and one for yellow. With each subsequent horizontal shift register pulse, a different group of three MOS transistors is activated, supplying the outputs from the different color groups to the three-color output lines.

The sequence continues until all the 384 sensors in the horizontal line have been scanned. After scanning the first pair of lines (lines 1 and 2), the vertical shift register shifts two lines, thus scanning lines 3 and 4, then lines 5 and 6, and then lines 7 and 8, until lines 484 and 485 are scanned. To scan a complete field on the next scan, lines 2 and 3, then 4 and 5, and so on are scanned.

As the technology improves, solid-state pickup devices will gradually replace tubes. In the future, smaller, lighter, and higher-performing cameras will become available.

THE MODERN TV RECEIVER

Figure 4-13 is a block diagram of a black-and-white TV receiver showing sound, picture, and synchronizing signal paths. These stages are:

- *RF amplifier*—amplifies all signals reaching the antenna and sends them to the mixer.
- *Local oscillator*—generates an RF signal and sends it to the mixer.
- *Mixer*—receives both the incoming signal and the local oscillator signal and beats (mixes) them together and sends the difference of their frequencies to the intermediate-frequency (IF) amplifiers.
- *IF amplifiers*—amplifiers (usually three) that amplify the signal and send it to the video detector.
- *Video detector*—separates the sound portion of the signal from the rest and sends it to the sound IF amplifiers. The rest of the composite signal is sent to the video amplifier.
- *Video amplifier*—amplifies the video and synchronization signals and sends them to the cathode-ray tube (CRT) and sync separator, respectively.
- *Sync separator*—separates the vertical and horizontal sync pulses and sends them to the vertical and horizontal oscillator stages.
- *Vertical oscillator*—provides the 60-Hz signal that is used to control the vertical movement of the scanning beam.
- *Vertical amplifier*—provides the current that is applied to the vertical windings of the deflection yoke on the neck of the CRT (picture tube).
- *Horizontal oscillator*—provides the 15,750-Hz signal that is used to control the horizontal movement of the scanning beam.
- *Horizontal amplifier*—provides the current that is applied to the horizontal windings of the deflection yoke on the neck of the CRT (picture tube). The horizontal amplifier also provides a pulse to the high-voltage (HV) rectifier.
- *HV rectifier*—provides the high voltage used to light up the face of the CRT.
- *First and second sound IFs*—amplify the sound signal and apply it to the sound detector.
- *Sound detector*—separates the sound signal from its RF carrier and sends it to the sound amplifier.

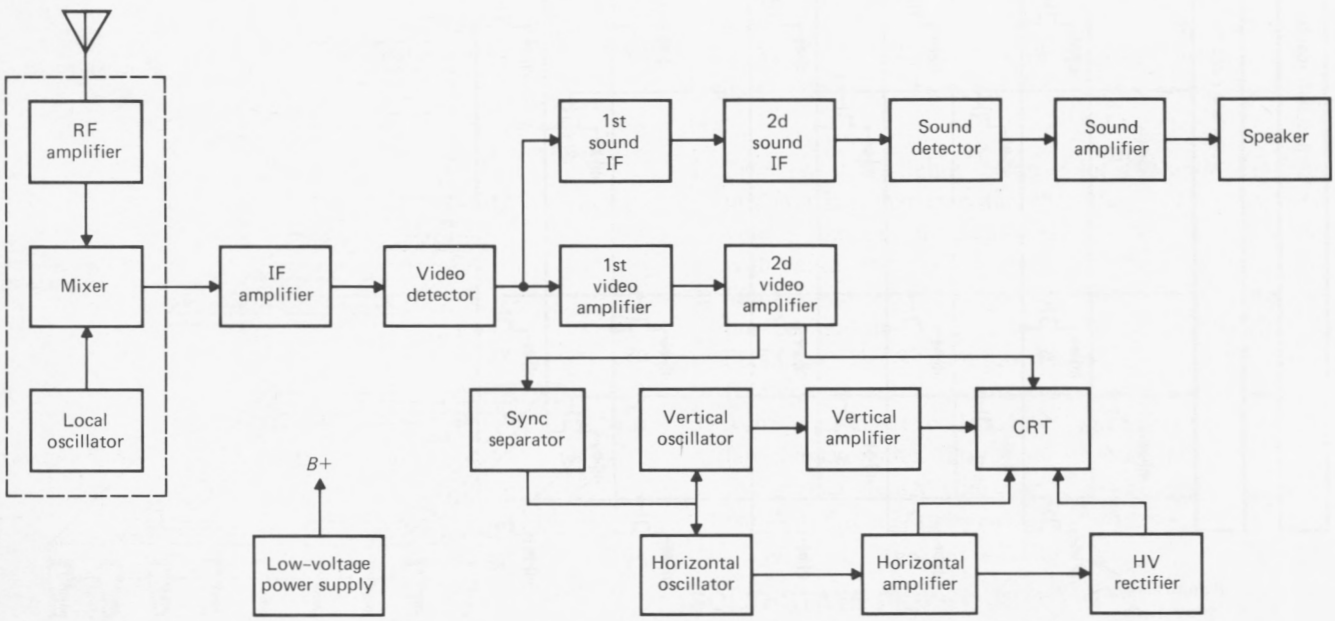


Fig. 4-13. Block diagram of black-and-white TV receiver.

- *Sound amplifier*—amplifies the sound signal to a level sufficient to operate the loudspeaker.
- *Speaker*—converts the electrical energy of the sound signal to sound energy.

NOTE: Collectively, the RF amplifier, the local oscillator, and the mixer compose the tuner of the TV receiver. Many of the functions listed above have been combined in recently manufactured solid-state sets.

SUMMARY

1. The head-end of a CATV system separates, processes, amplifies, and assigns channels on the cable system.
2. Television channel allocation is designed to minimize co-channel and adjacent-channel interference between commercial TV stations.
3. A basic TV system consists of various video and audio pickup devices (camera tube and microphones), signal processing equipment, transmitter, and receiving device.
4. The vertical scanning frequency is 60 Hz.
5. The horizontal scanning frequency is 15,750 Hz.
6. There are 525 active lines to a TV picture.
7. In interlace scanning there are 262½ lines to a field and two fields to a frame.
8. The standard TV signal consists of picture information, blanking pulses, and the picture synchronizing pulses.
9. Maximum white level is at 15 percent of the amplitude of the video signal.
10. Maximum black level is at 75 percent of the amplitude of the video signal.
11. Various kinds of video pickup devices are the (*a*) vidicon, (*b*) Trinicon, (*c*) Saticon, (*d*) Newvicon, and (*e*) MOS image sensor.

REVIEW QUESTIONS

1. What is a co-channel?
2. What is an adjacent channel?
3. What are the visual effects of co-channel interference?
4. How wide is a standard TV channel?
5. Explain the theory of operation of a vidicon tube.
6. Explain the theory of operation of the MOS image sensor.
7. At what percentage of the video signal is the maximum black level located?
8. Name three modifications to signals as they pass through the head-end equipment.
9. Name five pieces of head-end equipment.
10. Define interlace scanning.
11. What is the purpose of blanking pulses?
12. What is the function of the mixer in a TV receiver?

5 CHAPTER

CATV TRANSMISSION LINES

INTRODUCTION

In this chapter you will learn about:

1. Coaxial cable
2. Passive devices
3. Fiber-optic cable

In Chaps. 2 to 4 we saw how the signals from earth satellites and local broadcast stations are received and prepared for distribution. In this chapter we will cover coaxial cable and fiber-optic transmission lines. Also covered will be the various passive devices used to redirect, divide, and terminate signals on coaxial cable lines.

COAXIAL CABLE

Coaxial cable is the most common type of transmission line currently used in CATV. Coaxial cable consists of two conductors: one is hollow, and the other is located inside this hollow conductor. The term *coaxial* is used because both conductors have the same axis; thus they are coaxial. Figure 5-1 shows the principal parts of coaxial cable. When carefully manufactured, a coaxial cable insulated with a polyethylene dielectric will be uniform within 0.005 in. and there will be no air between the conductors. Thus, because of its uniform characteristics, it will operate indefinitely with low leakage and little risk of arc-over. Arc-over occurs when electrical current flows between the inner and outer conductor as a result of insufficient insulation.

Coaxial lines have two main advantages. First, the shielding is perfect for both magnetic and electrostatic fields. Looking at the two end views of the section of coaxial cable shown in Fig. 5-2, you can see that the electrostatic E field stops at the outer conductor. However, the magnetic H field from the inner conductor does extend beyond the outer conductor. But when an equal amount of current flows in the outer conductor, setting up its field, it cancels the field of the inner conductor. Hence there is neither an electrostatic nor a magnetic field outside the cable. Second, since a coaxial line does not radiate, it does not pick up any energy; therefore, it can be installed anywhere without being influenced by other strong fields.

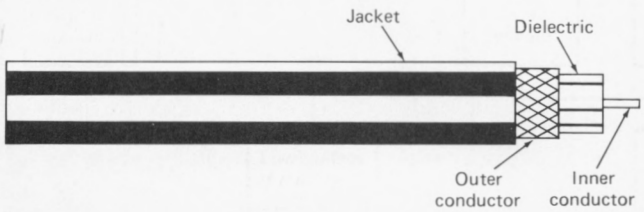


Fig. 5-1. Coaxial cable with protective jacket.

Characteristics of Coaxial Cable

Two of the most important characteristics of coaxial cable are attenuation and impedance. *Attenuation* is the reduction of signal strength in the cable due to cable length, temperature, and type of material and the cross-sectional area of the center conductor of the cable. Table 5-1 is an attenuation chart for various sizes of coaxial cable.

The *impedance* of the cable is its opposition to signal flow because of the inherent capacitance and inductance of the transmission line itself. The characteristic impedance of the coaxial cable used in CATV is 75 Ω. Characteristic impedance is the value of impedance that, when connected to the output of a transmission line, makes the line appear to be infinitely long. The characteristic impedance Z_0 of any coaxial cable may be found by using one of the following methods.

Finding Characteristic Impedance from Physical Dimensions

By knowing the dimensions of a coaxial line, you can mathematically determine its characteristic impedance by the equation

$$Z_0 = 138 \log_{10} \frac{D}{d}$$

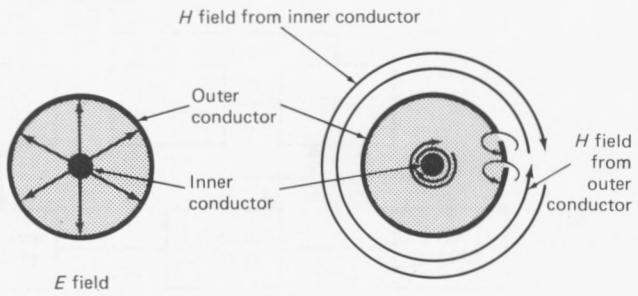


Fig. 5-2. Fields within coaxial cable.

TABLE 5.1 Coaxial Cable Attenuation Chart (dB/100 ft)

Frequency, MHz	*Maximum Attenuation at 68°F*						
	0.412 in.	*0.450 in.*	*0.500 in.*	*0.650 in.*	*0.750 in.*	*0.875 in.*	*1.00 in.*
5	0.23	0.17	0.14	0.12	0.10	0.09	0.07
30	0.58	0.41	0.35	0.28	0.25	0.21	0.18
55	0.77	0.56	0.48	0.38	0.34	0.27	0.24
83	0.94	0.69	0.59	0.47	0.41	0.36	0.30
100	1.06	0.75	0.65	0.51	0.45	0.39	0.33
175	1.39	1.01	0.86	0.69	0.60	0.52	0.45
211	1.52	1.11	0.95	0.76	0.66	0.55	0.49
250	1.65	1.21	1.03	0.83	0.72	0.63	0.54
270	1.73	1.26	1.08	0.86	0.75	0.67	0.56
300	1.81	1.33	1.14	0.91	0.79	0.70	0.60
312	1.85	1.36	1.16	0.93	0.81	0.72	0.61
325	1.88	1.39	1.19	0.95	0.83	0.75	0.62
350	1.95	1.44	1.23	0.99	0.86	0.78	0.65
375	2.02	1.49	1.28	1.02	0.88	0.80	0.67
400	2.11	1.54	1.32	1.06	0.91	0.83	0.70
425	2.18	1.59	1.36	1.09	0.94	0.86	0.72
450	2.24	1.64	1.40	1.13	0.97	0.89	0.74

where D is the inside diameter of the outer conductor and d is the diameter of the inner conductor.

EXAMPLE 1

Given that the inner conductor diameter is 0.250 in. and the outer conductor is 0.875 in. (inside diameter), find Z_0.

Solution

$$Z_0 = 138 \log_{10} \frac{D}{d}$$

$$= 138 \log_{10} \frac{0.875}{0.250}$$

$$= 138 \log_{10} 3.5$$

$$= 138 \times 0.5440 = 75.08$$

The characteristic impedance Z_0 equals 75 Ω.

Finding Characteristic Impedance from Graphs

Figure 5-3 is a graph that plots impedance against physical dimensions. This graph can be used to find the characteristic impedance of any coaxial cable. The horizontal values represent the ratio of D/d, and the vertical values represent the impedance in ohms.

To see how this graph is used, let us plot the value of D/d of Example 1 on the horizontal scale. Once plotted, move upward until you reach the heavy line, then move to the left until you reach the vertical scale. The characteristic impedance has now been found to be 75 Ω for a D/d ratio of 3.5.

In the cable industry, to ensure that the impedance is uniform, a specification known as *structural return loss* (SRL) is used. The SRL is a measure of how much signal is reflected as a result of an impedance mismatch. The reflective wave is a minimum of 26 dB down from the

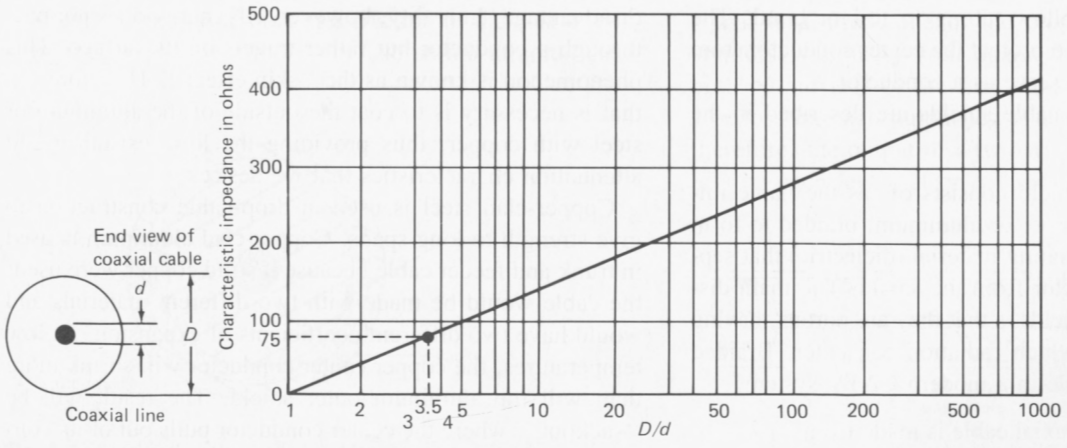


Fig. 5-3. Characteristic impedance graph for coaxial lines.

incident wave over the entire frequency range from 5 to 450 MHz. Methods of measuring SRL are covered in the Appendix.

Besides impedance, attenuation, and SRL, the cutoff frequency of the cable should also be known. The cutoff frequency of coaxial cable is that frequency, when reached, where the attenuation experiences a rapid rise in value.

For example, the cutoff frequency for ½-in. coaxial cable is 6 GHz, while 1-in. cable is only 2 GHz.

Uses of Coaxial Cable

Coaxial cable is generally classified according to its usage; therefore, we refer to coaxial cable as:

1. *Transportation trunk lines*—coaxial cables that run from an antenna site to the head-end. Typical lengths of transportation trunk cables are 500 ft.
2. *Distribution trunk lines*—coaxial cables that run from the head-end to the end of the distribution system.
3. *Distribution (feeder) lines*—a section of coaxial cable that is branched off from the distribution trunk and used to convey the CATV signals to the front or back of the subscriber's home. The feeder cable contains devices that allow signals to be tapped off for use by the subscriber.
4. *Subscriber drop lines*—coaxial cable that brings the signal from the tap-off device on the feeder cable into the subscriber's home.

The trunk and feeder lines are basically the same cable, only different in size. Trunk lines do not contain passive devices; feeder and subscriber drop lines do. Trunk cable is usually ¾ in. in diameter, while feeder cable is smaller, generally ½ or 0.412 in. in diameter. Subscriber drop cable, on the other hand, is about ¼ in. in diameter. Because drop cable does not have a solid outside conductor (shield), it is more flexible than trunk or feeder cable.

Parts of Coaxial Cable

Cable Shields

Coaxial cable shields are made from copper or aluminum and vary from rigid hollow tubing to foil or braid. The purpose of the shield is to protect the center conductor from outside radiation and to serve as a conductor.

The types of coaxial cable shields are described in the following paragraphs.

Braided. A braided shield consists of, as the name implies, thin strands of copper or aluminum, braided to form a covering over the insulating material (dielectric) that separates the center conductor from the shield. The main disadvantage of braided shields is that they are porous, having minute holes through which radiation can enter. Braided shields are not acceptable in a modern CATV system.

Strip. Strip-braided coaxial cable is made from wide copper strips instead of thin strands. The construction is the same as braided strands, but the strips have fewer holes for radiation to leak through.

Solid Aluminum. The solid aluminum shield provides almost 100 percent shielding from radiation. Solid shielding is accomplished by either placing the dielectric-covered center conductor into the aluminum tube and extruding it or by folding the long aluminum strip over the dielectric covered center conductor and welding the seam.

Aluminum Foil Tape. Because of the rigidity of solid aluminum shields, an alternative method had to be employed in subscriber drop-cable construction for flexibility. The methods commonly used to provide a flexible shield are:

1. To wrap aluminum foil around the dielectric lengthwise, overlapping the edges to provide for 100 percent shielding. Care must be taken when using this type of shielded cable because the shield might tear during installation of the fitting.
2. To bond (adhere) aluminum foil to the dielectric. One problem encountered with the use of bonded aluminum tape is that the foil might tear as a result of excessive flexing from movement of the earth in buried construction or from the wind in aerial construction.
3. To use a thick aluminum foil tape that is bonded to the jacket (outer covering) of the coaxial cable. Although this does provide excellent shielding, flexibility is compromised.

Cable Center Conductors

Coaxial cable center conductors are made of either solid copper, copper-clad aluminum, or copper-clad steel.

The size of the center conductor is determined by the characteristics of the cable and can range from 0.025 (No. 22 AWG) to 0.255 (No. 2 AWG) in. The center conductor, for the most part, determines the amount of attenuation exhibited by the cable. As can be seen in Table 5-1, as the size of the cable increases, the attenuation decreases.

Solid copper is rarely used today because of the cost. Instead, copper-clad aluminum or steel is the more common type of center conductor. It would appear that the use of aluminum or steel, with its greater resistance, would be a disadvantage. In reality, however, RF energy does not pass through a conductor but rather travels on its surface. This phenomenon is known as the "skin effect." Therefore, all that is necessary is to coat the outside of the aluminum or steel with copper, thus providing the low resistance and attenuation characteristics that we desire.

Copper-clad steel is used in drop-cable construction to give strength to long spans. Copper-clad aluminum is used in trunk and feeder cable because if solid copper were used, the cable would be made with two different materials and would have two different coefficients of expansion. At low temperatures, the copper center conductor will shrink more than will the aluminum outer shield. The result will be "suckout," where the center conductor pulls out of its connector.

Dielectrics

In Fig. 5-1 we can see that the space between the center conductor and the shield is filled with a material. This material is known as the *dielectric*. The more common materials used as dielectrics in coaxial cable are solid polyethylene and foamed polyethylene.

In the early days of CATV solid dielectrics were necessary because the braided shield did not offer sufficient strength to prevent flattening. Understandably, if the outer shield is not an equal distance from the center conductor, the characteristics of the cable will change. But with the advent of the solid shield, foam dielectrics came into use in all trunk and feeder cables. Because subscriber drop cable must be flexible, solid dielectrics are still used in it.

Protective Jackets

To prevent deterioration of coaxial cable from harsh environments such as salt air and industrial pollutants, a protective jacketing material is applied to the shield. The jacketing material may be either polyethylene or polyvinylchloride. To eliminate the possibility of water vapor entering between the jacket and the shield, a clear, sticky, "flooding compound" is applied before the jacket is put on. The material most commonly used as a flooding compound is polyisobutylene. This is a clear, viscous compound that does not harden under ambient temperatures and will flow to the damaged areas of the jacket. Figure 5-4 shows the construction of a jacketed cable with flooding compound between the shield and the jacket.

Other Types of Coaxial Cable

Armored Cable

Because of the danger of denting or crushing the coaxial cable used for underground installations, cable used for this purpose is further covered by a steel armor. Another coat of flooding compound and jacketing material is placed over this armor of corrugated steel tape.

Submarine Cable

A new type of armored cable now available is designed to offer submarine protection at a fraction of the cost of conventional steel tape armor. The submarine armored cable uses copper wire armor to give the cable the weight and strength needed for successful underwater applications.

This cable is available in 0.500-, 0.750-, and 1.00-in. sizes and is manufactured as follows. Bare coaxial cable is jacketed with polyethylene. A polyisobutylene flooding compound is then placed between this jacket and the shield. After this, a layer of copper wire is helically stranded around the cable and covered with an asphalt flooding compound. The entire cable is then jacketed with black polyethylene.

Fused-Disk Cable

Fused-disk construction is shown in Fig. 5-5. In fused-disk coaxial cable, spacer disks are installed to maintain the correct distance between shield and center conductor and air is used as the dielectric.

PASSIVE DEVICES

Passive devices are those components of a CATV system whose main function is to divide, redirect, or terminate signal flow. All passive devices, including coaxial cable, take energy from the CATV system. As was pointed out earlier, impedance matching of the coaxial cable is very important. Therefore, for removal of signals from the cable, only devices designed to ensure a good impedance match and minimize signal losses should be used. Some of the more common passive devices used to accomplish the dividing, redirecting, or terminating of CATV signals while maintaining a good impedance match are (1) signal splitters, (2) directional couplers, (3) multitaps, (4) matching transformers, and (5) terminators.

Signal Splitters

When it is necessary to divide cable signals into two, three, or four paths, a signal splitter is utilized. A signal splitter is a circuit that allows the input power to be divided and yet maintains the 75-Ω characteristic impedance on the output legs. Shown in Fig. 5-6 are the symbols for two-way, three-way, and four-way signal splitters.

The three- and four-way signal splitters are combinations of two-way signal splitters. When a three-way division of signal is desired, one of the output legs of the two-way splitters is actually split again. For a four-way division, both output legs of the first signal splitter are split again. The loss on each output leg of a signal splitter is 3.5 dB; therefore, the output of a two-way signal splitter is 3.5 dB less on each leg, that on a three-way signal splitter is 7.0

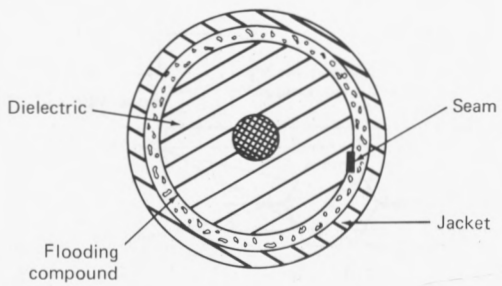


Fig. 5-4. Jacketed cable with flooding compound.

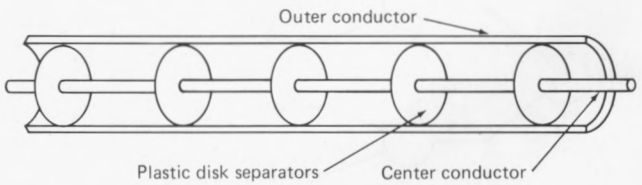


Fig. 5-5. Fused-disk cable construction.

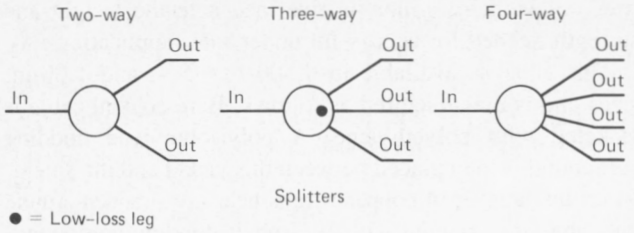


Fig. 5-6. Signal splitter symbols.

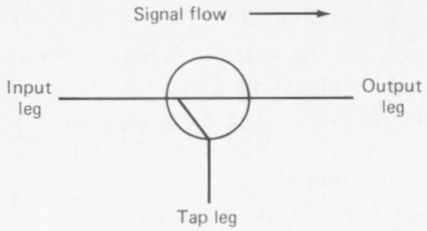


Fig. 5-8. Directional coupler symbol.

dB on two legs and 3.5 on the third, and that on a four-way signal splitter is 7.0 dB on each leg. Figure 5-7 shows the output signals on each of these splitters with an initial input signal of 10 dB.

Directional Couplers

A directional coupler is a device used to remove a portion of signal for use elsewhere. Directional couplers may be used to redistribute signals, provide test points for test equipment, or combine head-end signals. The unique feature of a directional coupler is that it acts as a one-way device, allowing signals to be tapped off but restricting the flow of signals in the opposite direction. The directional coupler has an input, output, and tap leg as shown in Fig. 5-8. The loss of signal due to insertion of this device (insertion loss) is approximately 1 dB. A directional coupler may be part of an amplifier or a separate unit with its own housing.

Multitaps

A multitap is a unit placed in the feeder cable to enable a portion of the signal to be sent to the subscriber. Multitaps are built with two-, four-, or eight-output connectors called "ports." Multitaps are placed on the cable at alternate poles.

Because only enough signal to provide good reception has to be tapped off, multitaps are made in various values of attenuation. It is customary in the CATV industry to provide about 10 dB of signal at the ports for subscriber connection. Thus, a 26-dB multitap would be required if the signals on the cable were 36 dB. On the other hand, if the cable had only 18 dB of signal at that point, an 8 dB of multitap would be used. Figure 5-9 shows the map symbols used for multitaps.

Matching Transformers

A matching transformer is used to match the impedance of the coaxial cable (75 Ω) to the input impedance of a standard TV receiver (300 Ω). Impedance-matching transformers are step-up transformers with a 1:2 turns ratio. Figure 5-10 shows a CATV matching transformer.

Terminators

A terminator is a device used to match a coaxial cable to its characteristic impedance. Most terminators contain a 72-Ω resistor that is placed across both the inner and outer conductors.

FIBER-OPTIC CABLE*

As the CATV industry expands, it faces major challenges. It must provide larger and more complex system capacities, distribute signals of higher quality in hostile environments, establish greater reliability, and balance rising costs with more cost effective technology. Fiber optics is beginning

*The copy for this section (through page 59) was adapted from: Deichmiller, A. C. and Alan H. Kent, "Fiber Optics for CATV," *Optical Spectra*, September 1981, Copyright 1981 The Optical Publishing Co. Inc., All rights reserved; and "A Brief Look at Fiber Optic Communication," a paper by A. C. Deichmiller, with permission of *Times Fiber Communication, Inc.*

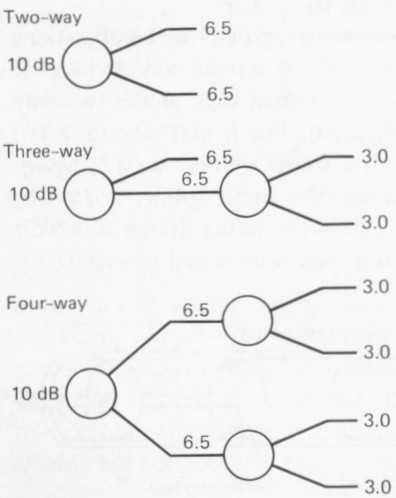


Fig. 5-7. Signal loss on two-, three-, and four-way splitters.

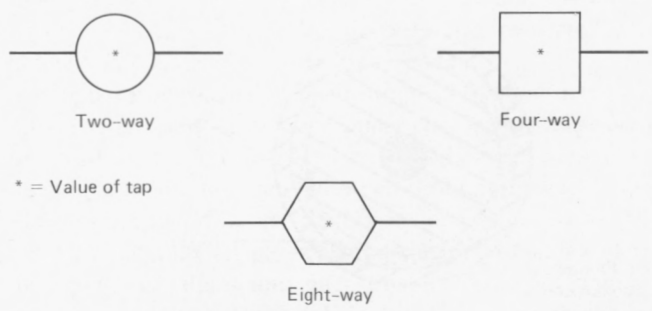


Fig. 5-9. Symbols for multitaps.

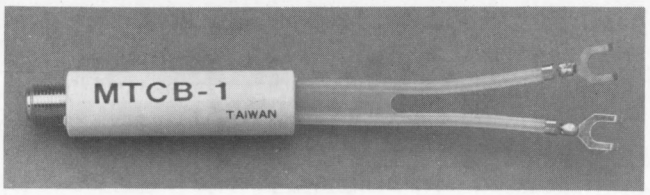


Fig. 5-10. CATV matching transformer *(CWY Electronics)*.

to result in significant changes in the CATV industry: as a new means of transmitting TV signals, the use of fiber-optic cable is proving able to meet the challenges.

Fiber-optic cable is made up of fine strands of glass fibers that are used to carry modulated light energy. Instead of placing a signal on a wire conductor, the signal is used to modulate the light generated by a source such as a laser. This modulated light is then fed into a fiber-optic strand and sent to a receiver, where the signal is recovered.

In conventional CATV systems, the signals are transmitted on coaxial cables and amplifiers are placed periodically along the cable to compensate for the signal losses. But there are well-defined limits on how many miles of cable and associated amplifiers can be used in a CATV system. Every segment of the system contributes some noise, seen as "snow" in a TV picture, and amplification of the signal also increases the noise level. So eventually amplification reaches a point beyond which additional cable and amplifiers cannot be used without producing substandard reception. This is where fiber optics come in.

Beginnings of Fiber Optics

In 1854 John Tyndall formulated the principle of total internal reflection on which the operation of fiber optics is based. He theorized that light in a dense optical medium could not escape to a less dense medium if the reflecting angles of the light rays were sufficiently low.

Figure 5-11 shows a cross section of a step index glass fiber. The narrow cladding around the fiber is the less dense medium. Any light rays entering the fiber within the acceptance cone will propagate to the other end. Any light rays beyond this acceptance cone are eventually lost.

During the late eighteenth and early nineteenth centuries very little development took place, but in 1927 two patents were issued: one in the United States and one in England. Both patents dealt with the use of optical fibers for optical image transmission. As a result, medical instruments were developed that allowed physicians to view inside the human body without major surgery; image intensifiers were invented for aiding night vision; and commercially available fiber-optic lamps were created.

Development of the Laser

In 1960, the laser (light amplification by stimulated emission of radiation) was invented. In simple terms, a laser is a light source that can be of very high intensity and whose light output is coherent. In this case, we can define the term *coherent* as light of the same wavelength. A light bulb radiates light, but its output is spread over the visual wavelength spectrum on into the infrared range.

Today, lasers have many uses such as drilling and cutting metals, cutting cloth for clothing, precise measurement systems, and—of course—communications systems. A common communications method is to modulate a laser beam and allow this narrow beam to pass through the atmosphere to an optical receiver composed of a photocell and an electronic amplifier. This system works, but moisture, dust, pollen, and other particles from the atmosphere can cause light scatter and, consequently, unreliable operation.

Before the use of optical fibers for communications could be considered seriously, two specific technical problems had to be overcome:

1. *The reduction of optical fiber transmission loss.* This has occurred with remarkable speed. For instance, in 1968 typical fiber loss was 1000 dB/km. Since 1980, fiber has been produced with attenuation values of 2 to 6 dB/km in standard production. As an example, let us assume that we could place 1000 W of optical power into a fiber-optic cable. In 1970 the loss was 20 dB/km, which would mean that after transmission to the opposite end of a 1-km cable we would receive only 10 W of power. Today, with 4-dB/km fiber we would have 400 W of received power—a substantial difference, indicating the ability to make much longer transmission runs.
2. *The development of a high-energy optical source.* Light-emitting diodes (LEDs) and laser diodes both existed at the time, but there were two serious problems: they had the wrong wavelength output for fiber optics and were short-lived. Aluminum galium arsenide semiconductor lasers operating at around 800 μm in wavelength were first used in 1970. The life expectancy of these devices

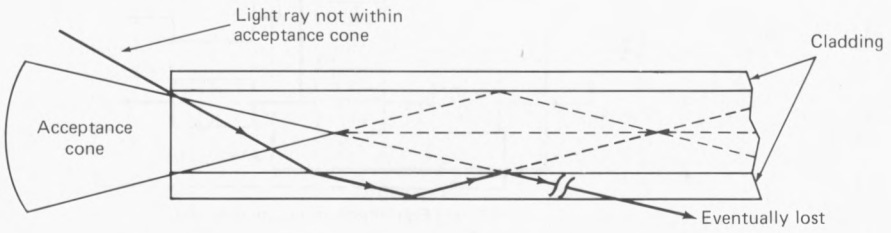


Fig. 5-11. Optic fiber cross section *(Times Fiber Communications)*.

was very low, but again, rapid advancement was made. From a life expectancy of 2 h in 1970, life expectancy has increased to 100,000 h at present. This is the type of laser used today for fiber-optic broad-band (CATV) systems. The laser can couple approximately 1000 W of optical power into standard production-type fibers.

Present Fiber Types

At present, the three most important types of optic fibers used are the multimode graded-index fiber, multimode step-index fiber, and the single-mode fiber. As research continues, it is expected that newer and better types of fiber will be developed.

Multimode graded-index fiber is the type used in current fiber-optic transport systems. Its characteristics are broad bandwidths (2 GHz/km have been obtained). Production fibers range in the 1 GHz and under bandwidths, per kilometer length.

Transmission of wide-band communications signals long distances, with fiber optics, requires the use of lasers. Frequency modulation is the preferred method of transmission in fiber transport systems today. The intensity of the laser is varied by an FM signal, which is used as the input to the transmitter. At the other end of the fiber, the optical receiver senses the light from the transmitter and recreates the original FM signal.

A very significant benefit of frequency modulation is a distinct improvement in signal-to-noise (S/N) ratios. Generally, the wider the frequency deviation, the greater the S/N improvement. For example, standard FM modulators provide more than 20 dB of improvement in S/N. Wide-band modulators provide well over 30 dB of S/N improvement. This translates to a capability to provide multichannel fiber-optic systems over 30 mi long end to end while retaining over 50-dB constant S/N ratios. This is virtually impossible, technically or economically, with other transport techniques.

Multichannel fiber transport systems are attained by centering the frequencies of the various FM channels on different portions of the usable transmission spectrum of the laser. Standard laser transmitter spectral width is in one example: 30 to 300 MHz. Therefore, five-channel center frequency spacing can be at 70, 123, 182, 230, and 276 MHz, respectively. These center frequencies are provided as the output from a multiplexer. Their values are chosen to minimize second- and third-order harmonics, with excellent results.

Point-to-Point Fiber Transport Systems

In this example (Fig. 5-12), five channels of baseband video are fed individually into FM modulators. The resulting output from each modulator is an FM signal at a center frequency of 70 MHz. These five 70-MHz channels are fed into a multiplexer which up-converts each signal to a different center frequency of the laser transmitter (30 to 300 MHz). This combined FM signal of the five channels is then fed into the transmitter, where it is used to vary the intensity of the laser source.

At the receiving end, light received by the avalanche photodiode (APD) receiver is converted back to the FM signal, which is demodulated back to baseband at the demodulators in exact reverse to the previous procedure. Signal quality remains very high, and distances of up to 30 mi are practical and possible with the use of repeaters.

TVRO Links

In some cases, the distance from the satellite receiving site to the head-end may be greater than 0.5 mile. In this case, a fiber-optic transport system will provide an excellent means

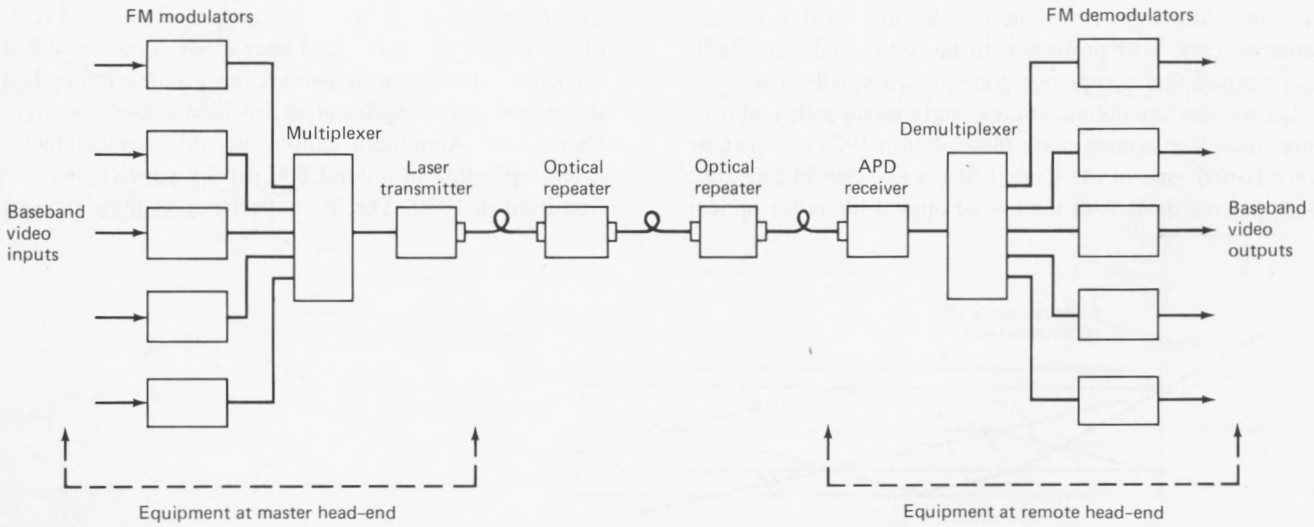


Fig. 5-12. Point-to-point fiber transport system *(Times Fiber Communications)*.

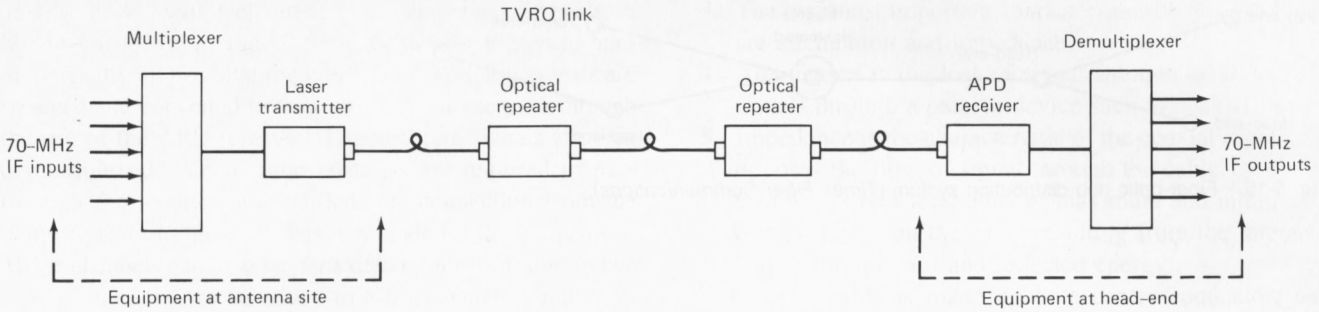


Fig. 5-13. TVRO links *(Times Fiber Communications).*

to transport these signals without the need for signal demodulation and remodulation. Figure 5-13 shows how a TVRO link might be constructed.

At the satellite antenna site, signals are converted down to 70 MHz IF by individual satellite receivers. The FM signals ($\pm$ 10.75 MHz) are then fed into the fiber transport system directly. At the head-end, the received light signal is demultiplexed into the original signals, which can then be fed into a second set of satellite receivers for conversion to baseband.

Fiber Transmission Systems for Satellite Earth Stations

The fiberblock system (Fig. 5-14) consists of a down converter and an optical transmitter installed in a weather-resistant case mounted to the antenna structure. The down converter converts the 3.7- to 4.2-GHz output of the LNA to a 0.6- to 1.1-GHz RF signal which is used to modulate the transmitter. This 500-MHz band contains all 24 transponder channels (12 horizontal and 12 vertical). A single fiber can carry this signal up to 3280 ft to the optical receiver located at the head-end. The RF output of the optical receiver is then up-converted back to the 3.7- to 4.2-GHz band, where it can be fed to as many as 12 standard satellite receivers.

For systems requiring 24 channels (12 vertical and 12 horizontal), two fiberblock systems may be mounted together, each utilizing a single fiber. In either case, change in signal quality is virtually undetectable and nonmeasurable with standard test equipment. Because of its superior performance and elimination of the need for a building to house the equipment, the fiberblock system provides an excellent solution for remote antennas at a distance of up to 3280 ft.

Fiber-Optic Hub Distribution Systems

Figure 5-15 shows the use of fiber-optic cables to provide links between a master head-end and smaller "hub" head-ends. Each link in this configuration can be viewed as a simple point-to-point system. Alternative head-end configurations are possible for handling virtually all CATV applications.

Remote Locations

Remote locations generally assume one of two configurations. In a *drop location,* the needs of the location are limited to having "access only" to the channels on the fiber passing that location. No channel switching or local insertion is required. Figure 5-16 illustrates the configuration of a drop location. An important aspect of this configuration is that no remodulation of signals is necessary as they pass through the node. The signals are simply split after passing through the APD receiver, demultiplexed, and demodulated to baseband. The resulting channels are then available for local use. When complete flexibility is necessary to insert

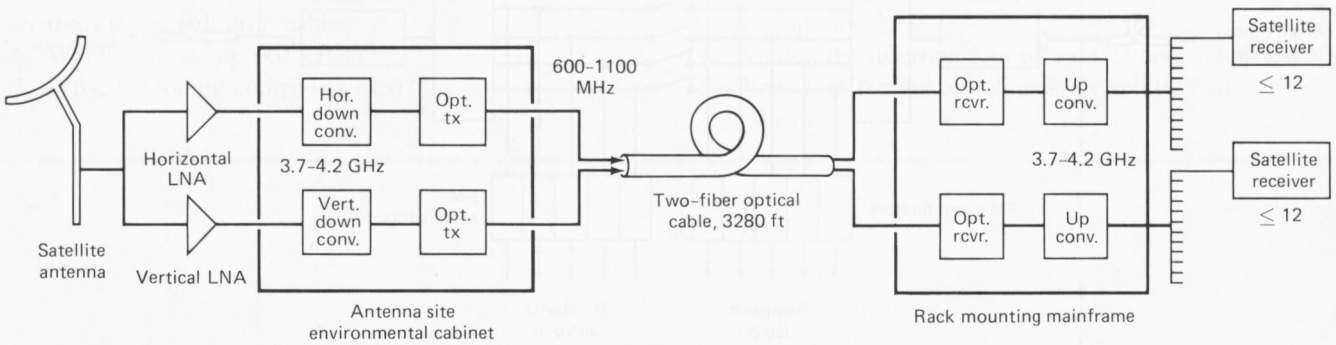


Fig. 5-14. Fiber transmission systems for satellite earth stations *(Times Fiber Communications).*

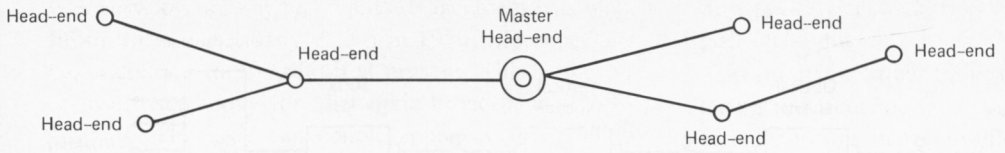


Fig. 5-15. Fiber-optic hub distribution system *(Times Fiber Communications)*.

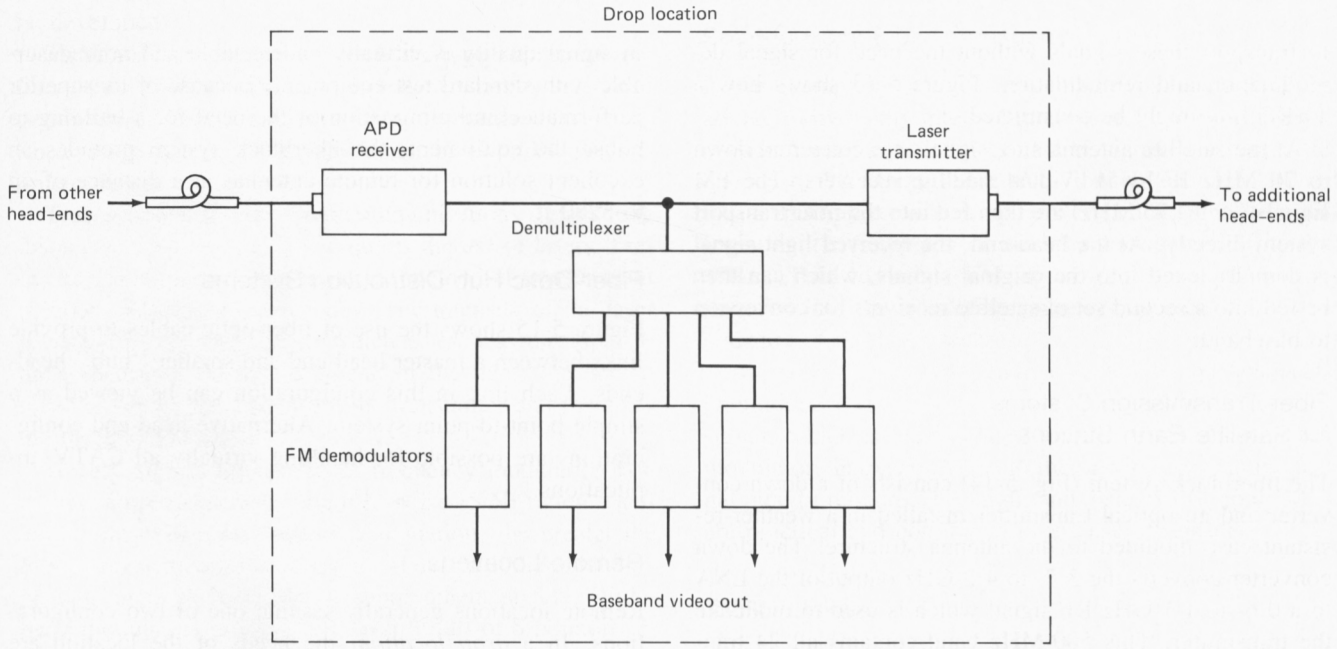


Fig. 5-16. Fiber-optic drop location *(Times Fiber Communications)*.

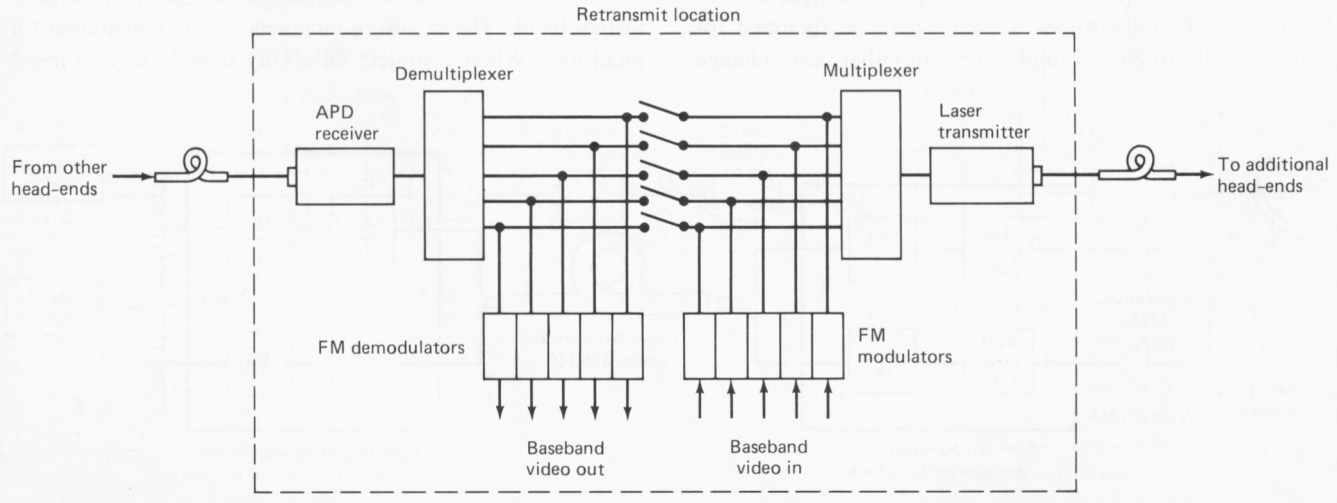


Fig. 5-17. Fiber-optic retransmit location *(Times Fiber Communications)*.

new signals, switch channels, and terminate channels, a *retransmit location* (Fig. 5-17) provides the means to handle virtually all possible requirements. Incoming signals are received and converted to their electrical counterparts through the use of the APD receiver. The resulting signals are then demultiplexed. When some channels are required to pass through the location unmodified, the connection from the demultiplexer to the multiplexer is made for these channels. These channels can also be demodulated for local use. When a new channel is to be added to a fiber which is not completely utilized, the new channel is modulated and simply added to the existing channels at the multiplexer. As shown in Fig. 5-17, up to five new channels can be added or replace existing channels on the fiber which runs through this location.

Through the use of switching equipment, practically any signal origination or termination need can be satisfied. For example, configurations have been designed for sophisticated networks which require alternate path capabilities. Through the use of multiple fibers in a retransmit configuration, a ready solution to this requirement is possible. Local or bidirectional program insertion is handled similarly. The outputs from the FM modulator can be fed simultaneously to multiplexers, which are connected to fiber-optic cables running in alternate directions.

SUMMARY

1. The CATV system is made up of two major sections, the head-end and the distribution system.
2. Coaxial cable is the transmission line used in most modern cable systems.
3. The two most important characteristics of coaxial cable are attenuation and impedance.
4. Attenuation is the loss of signal strength as the signal travels through a passive device such as coaxial cable.
5. Impedance is the characteristic of the coaxial cable that opposes the flow of signal through the cable.
6. Standing waves are points of maximum and minimum voltage levels on the cable resulting from the interaction of the forward and reflected energy.
7. Coaxial cable is made up of a center conductor, an outer shield, and an insulating material between them called the *dielectric*.
8. Coaxial cable shields may be solid, braided, or foil tape.
9. Center conductors may be solid, copper, copper-clad aluminum, or copper-clad steel.
10. To prevent water vapor from entering coaxial cable, a flooding compound is applied between the jacket and the shield.
11. Another type of transmission line used in distribution systems is fused-disk coaxial cable.
12. Passive devices found in CATV distribution systems include splitters, coaxial cable, directional couplers, multitaps, and matching transformers.
13. Fiber-optic cable is made up of fine strands of glass fibers that are used to carry modulated light.
14. Fiber-optic cable is used in CATV systems for supertrunk, TVRO links, and hub distribution purposes.
15. The three types of fiber-optic cable in use today are the multimode graded-index, multimode step-index, and single-mode fibers.

REVIEW QUESTIONS

1. What are the three parts of coaxial cable excluding the jacket?
2. Name two methods of finding the impedance of coaxial cable.
3. What is the characteristic impedance of coaxial cable used in CATV?
4. What does the acronym VSWR stand for?
5. What is the major difference in construction between trunk cable and drop cable?
6. What is meant by skin effect?
7. Why is flooding compound used?
8. Why do some localities need jacketed cable while others do not?
9. Describe the construction of armored cable.
10. Name three passive devices connected to coaxial cable.
11. Describe a fiber-optic cable.
12. Describe how fiber-optic cable is used to distribute CATV signals.
13. What is the loss in decibels on each leg of the two-way splitter?
14. What is the insertion loss of a directional coupler?
15. What does the dot on a three-way splitter map symbol indicate?

6 CHAPTER

SUPPLYING POWER TO CATV AMPLIFIERS

INTRODUCTION

In this chapter you will learn about

1. The parts of a basic power supply and the purpose of each
2. The purpose of various types of rectifier circuits.
3. The purpose of various types of filter circuits
4. The operation of various voltage and current regulators
5. Standby power supplies

Cable TV amplifiers are used to amplify the weak signals on the transmission line due to attenuation of the cable. Before studying these amplifiers, let us first discuss basic power supplies. A power supply is a collection of circuits that supply electronic devices with the voltages and currents needed for their proper operation.

THE BASIC POWER SUPPLY

Figure 6-1 shows the block diagram of a basic power supply. Cable TV power supplies consist of four basic sections: a transformer, a rectifier, a filter, and a regulator.

The *transformer* steps up or steps down the input voltage and isolates the power supply from the power line. The *rectifier* section converts the ac input voltage to a pulsating dc voltage. However, pulsating dc is not desirable. For this reason a *filter* section is used to convert pulsating dc to a purer, more desirable form of dc voltage.

The final section, the *regulator,* maintains the output of the power supply at a constant level despite large changes in load current or input line voltage.

The Transformer

A transformer is an electrical device that transfers ac energy from one circuit to another by magnetic coupling of the primary and secondary windings. This is accomplished through mutual inductance M. When voltage is applied to the primary of a transformer, exciting current flows in the primary. The current causes a magnetic field to be set up around both the primary and secondary windings. This moving field (flux) causes a voltage to be induced into the secondary windings. An ideal transformer is one where all the magnetic lines of force produced by the primary cut the entire secondary. The turns ratio of a transformer is the ratio of the number of turns of wire in the primary windings to the number of turns in the secondary winding. When the turns ratio is stated, the number representing turns on the primary is always stated first. For example, a 1:2 turns ratio means that the secondary has twice the number of turns as the primary. In this example, the voltage across the secondary is twice the voltage applied to the primary.

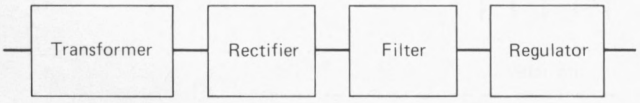


Fig. 6-1. Block diagram of a basic power supply.

The Rectifier

Rectification is the changing of an ac voltage to a pulsating dc voltage. Now let us see how the process of rectification occurs in both a half-wave and a full-wave rectifier.

The Half-Wave Rectifier

Since a silicon diode will pass current in only one direction, it is ideally suited for converting alternating current to direct current. When ac voltage is applied to a diode, the diode conducts *only on the positive alternation of voltage;* that is, when the anode of the diode is positive in respect to the cathode. This simplest type of rectifier is the half-wave rectifier. As shown in Fig. 6-2*a*, the half-wave rectifier uses only one diode (D_1). During the positive alternation of input voltage, the sine wave applied to the diode renders the anode positive with respect to the cathode. The diode then conducts, and current I flows from the negative supply lead (the secondary of the transformer) through the load resistor, the diode, and the positive supply lead. As indicated by the shaded area of the output waveform in Fig. 6-2*b*, this current exists during the entire period of time that the anode is positive in respect to the cathode (in other words, for the first 180° of the input sine wave).

During the negative alternation of input voltage (dotted polarity signs), the anode is driven negative and the diode cannot conduct. When conditions such as these exist, the diode is in cutoff and remains there for 180°, during which time no current flows in the circuit. The circuit current thus

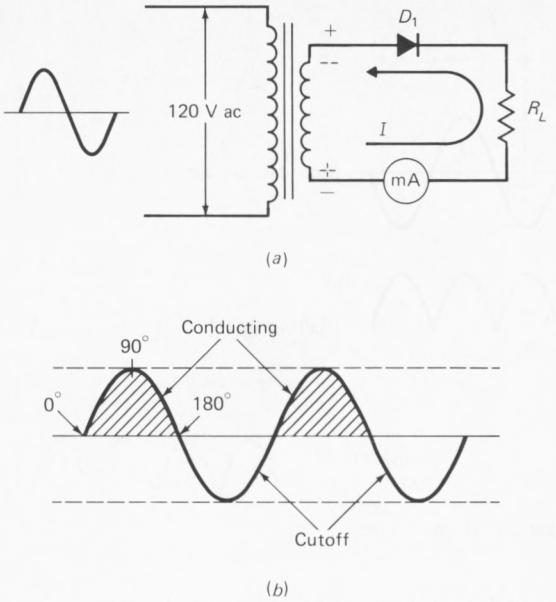


Fig. 6-2. Simple half-wave rectifier; (*a*) half-wave rectifier; (*b*) output waveform.

has the appearance of a series of positive pulses, as illustrated by the shaded areas on the waveform in Fig. 6-2*b*. Notice that although the current is in the form of pulses, the current always flows in the same direction. Current that flows in pulses in the same direction is called *Pulsating dc*. The diode has thus rectified the ac input voltage.

RMS, Peak, and Average Values

Figure 6-3*a* presents a comparison of the rms, peak, and average values of the types of waveforms associated with the half-wave rectifier. Alternating-current voltages are normally specified in terms of their rms values. Thus, when a 115-V ac power source is mentioned, it specifies the rms value of 115 V ac in terms of peak values:

$$V_{rms} = V_{peak} \times 0.707$$

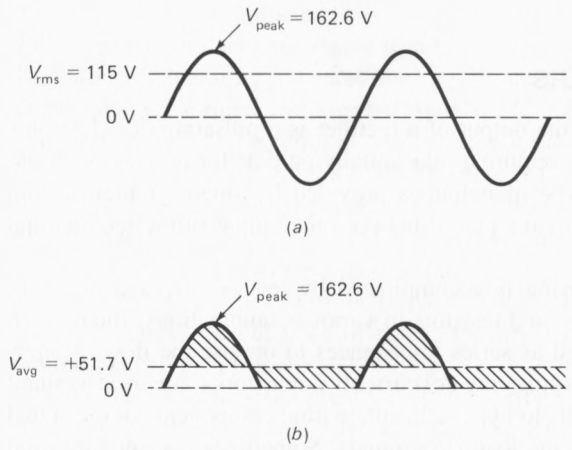


Fig. 6-3. Half-wave rectifier waveform values (*a*) input (*b*) output.

The peak value is always higher than the rms value. In fact

$$V_{peak} = V_{rms} \times 1.414$$

Therefore, if the rms value is 115 V ac, then the peak value must be

$$V_{peak} = V_{rms} \times 1.414 = 115 \text{ V ac} \times 1.414 = 162.6 \text{ V}$$

The average value of a sine wave is 0 V. Figure 6-3*b* shows how the average voltage changes when the negative portion of the sine wave is clipped off. Since the waveform swings positive but never negative (past the 0-V reference line), the average voltage is positive. The average voltage V_{avg} is determined by the equation

$$V_{avg} = V_{peak} \times 0.318 = 162.6 \times 0.318 = 51.7 \text{ V}$$

Ripple Frequency

The term *half-wave rectifier* derives from the fact that it conducts during only half of the input cycle. Its output is a series of pulses with a frequency that is the same as the input frequency. Thus when operated from a 60-Hz line, the frequency of the pulses is 60 Hz. This is called the *ripple frequency*.

The Full-Wave Rectifier

A full-wave rectifier circuit is shown in Fig. 6-4*a*. It uses two diodes (D_1 and D_2) and a transformer with a center-tapped primary (T_1). When the center tap is grounded, the voltages at the opposite ends of the secondary windings are 180° out of phase with each other. Thus, when the voltage at point *A* is positive with respect to ground, the voltage at point *B* is negative with respect to ground. Let us examine the operation of the circuit during one complete cycle.

During the first half cycle (indicated by the solid arrows), the anode of D_1 is positive with respect to ground and that of D_2 is negative. As shown, current flows from ground, up through the load resistor R_L, and through diode D_1 to point *A*. In the transformer, current flows from point *A*, through the upper winding, and back to ground through the center tap. When D_1 conducts, it acts like a closed switch so that the positive half cycle is felt across the load R_L.

During the second half cycle (indicated by the dotted lines), the polarity of the applied voltage has reversed. Now the anode of D_2 is positive with respect to ground and the anode of D_1 is negative. Now only D_2 can conduct. Current now flows, as shown, from ground, up through the load resistor R_L, through diode D_2 to point *B* of T_1. In the transformer, current flows from point *B* up through the lower windings and back to ground through the center tap. Notice that the current flows through the load resistor R_L in the same direction for both halves of the input cycle.

Figure 6-4*b* represents the output waveform from the full-wave rectifier. The waveform consists of two pulses of current (or voltage) for each cycle of input voltage. The ripple frequency at the output of the full-wave rectifier is thus *twice the line frequency* (120 Hz).

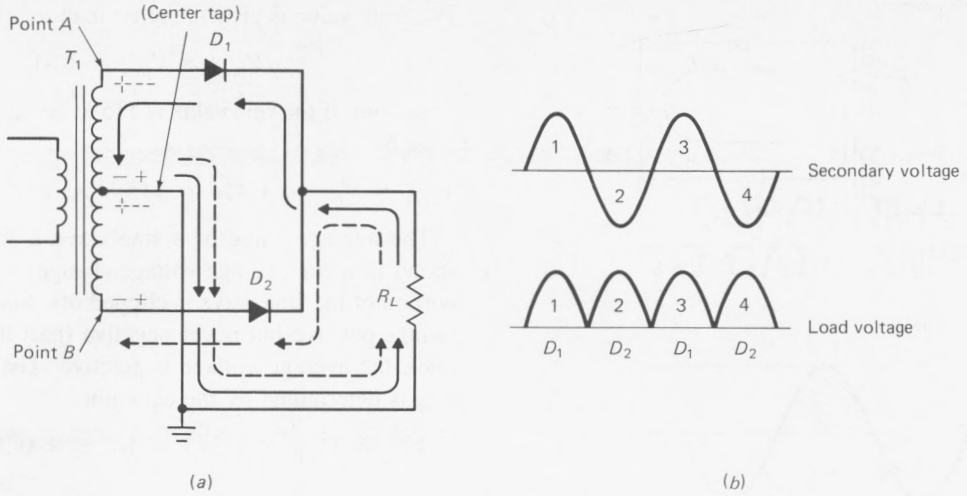


Fig. 6-4. Practical full-wave rectifier: (*a*) rectifier circuit; (*b*) associated waveforms.

The higher frequency at the output of a full-wave rectifier offers a distinct advantage: because of the higher ripple frequency, the output closely resembles pure dc. The higher frequency also makes filtering much easier than it is for the output of the half-wave rectifier.

The Bridge Rectifier

When four diodes are connected as shown in Fig. 6-5, the circuit is called a *bridge rectifier*. The input to the circuit is applied to the diagonally opposite corners of the circuit, and the output is taken from the remaining two corners.

One complete cycle of operation is discussed here to help you understand how this circuit works. Let us assume that there is a positive potential at point A and a negative potential at point B. The positive potential at point A will forward-bias D_3 and reverse-bias D_4. The negative potential at point B will forward-bias D_1 and reverse-bias D_2. At this time D_3 and D_1 are forward-biased and will allow current flow to pass through them; D_4 and D_2 are reverse-biased and will block current flow. The path for current flow is from point B through D_1, up through R_L, through D_3, and through the secondary of the transformer back to point B. This path is indicated by the solid arrows. Waveforms 1 and 2 can be observed across D_1 and D_3.

One-half cycle later the polarity across the secondary of the transformer reverses, forward-biasing D_2 and D_4 and reverse-biasing D_1 and D_3. Current flow will now be from point A through D_4, up through R_L, through D_2, through the secondary of T_1, and back to point A. This path is indicated by the broken arrows. Waveforms 3 and 4 can be observed across D_2 and D_4. You should have noted that the current flow through R_L is always in the same direction. In flowing through R_L this current develops a voltage corresponding to that shown in waveform 5. Since current flows through the load R_L during both half cycles of the applied voltage, this bridge rectifier is a full-wave rectifier.

One advantage of a bridge rectifier is that with a given transformer the bridge rectifier produces a voltage output that is nearly twice that of the conventional full-wave circuit.

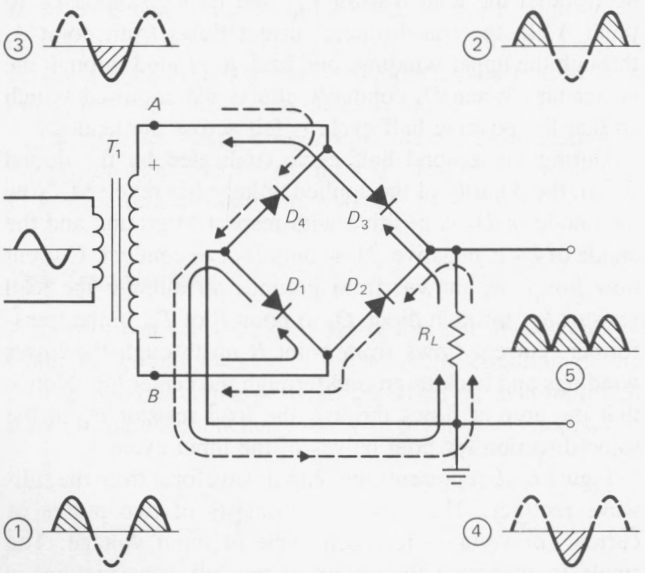


Fig. 6-5. Bridge rectifier circuit.

FILTERS

While the output of a rectifier is a pulsating dc, electronic circuits require a substantially pure dc for proper operation. This type of output is provided by single or multisection filter circuits placed between the output of the rectifier and the load.

Filtering is accomplished by the use of capacitors, inductors, and resistors in various combinations. Inductors L are used as series impedances to oppose the flow of alternating (pulsating dc) current. Capacitors C are used as shunt elements to bypass the alternating components of the signal around the load (to ground). Sometimes resistors are used in place of inductors in low-current applications.

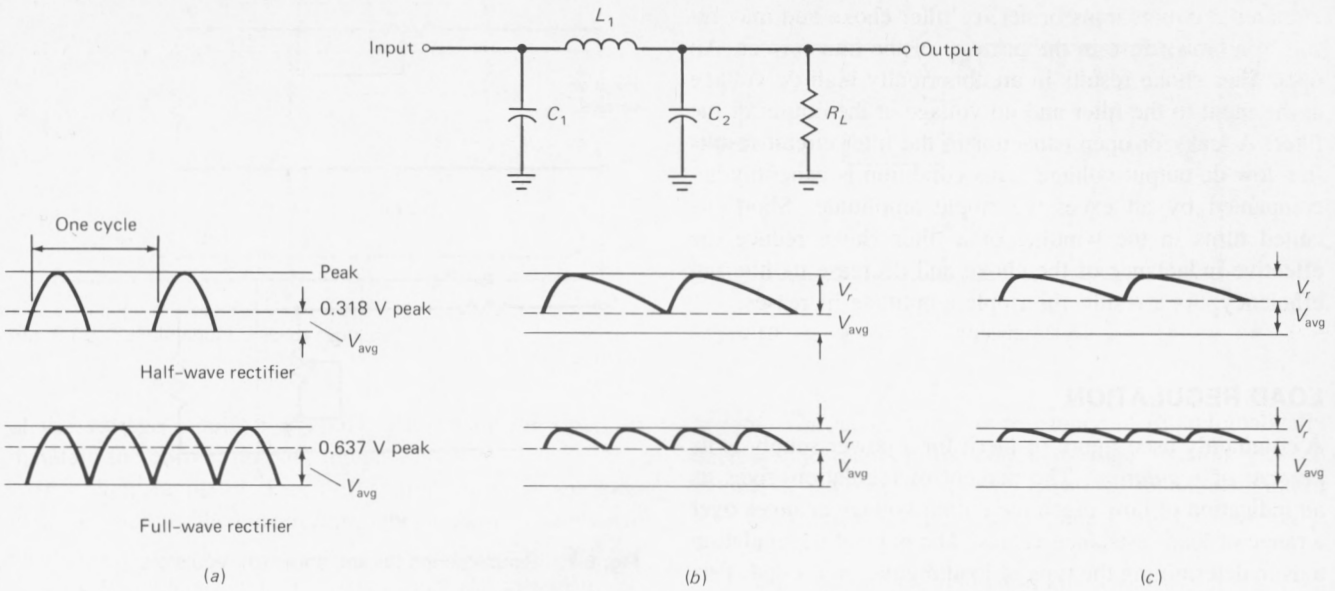


Fig. 6-6. LC filter and waveforms: (*a*) unfiltered output voltage from rectifier; (*b*) voltage across capacitor C_1; (*c*) voltage across capacitor C_2.

LC Capacitor-Input Filter

The *LC* capacitor-input filter is one of the most commonly used filters. This type of filter is used primarily where the output current is low and the load current is relatively constant.

Figure 6-6 shows an *LC* capacitor-input filter and associated waveforms. Both half- and full-wave rectifier circuits are used to provide the input. The waveforms shown in Fig. 6-6*a* represent the unfiltered output from a typical rectifier circuit. Note that the average value of output voltage E_{avg}, indicated by the dashed lines, for the half-wave rectifier is less than half the amplitude of the voltage peaks. The average value of output voltage E_{avg} for the full-wave rectifier is greater than half but is still much less than the *peak* amplitude of the rectifier-output waveform. With no filter connected across the output of the rectifier circuit (which results in unfiltered output voltage), the waveform has a large value of pulsating component (ripple) as compared to the average (or dc) component.

Capacitor C_1 reduces the ripple to a relatively low level (Fig. 6-6*b*). Inductor L_1 and capacitor C_2 form the *LC* filter, which reduces the ripple even further. Inductor L_1 is a large-value iron-core inductor (choke), and because it has a high value of inductance, it offers a high inductive reactance to the ripple frequency. At the same time, C_2 offers a very low reactance to ac ripple. Together L_1 and C_2 form an ac voltage divider, and, because the reactance of L_1 is much higher than that of C_2, most of the ripple voltage is dropped across L_1. Only a slight trace of ripple appears across C_2 and the load (Fig. 6-6*c*).

While the L_1-C_2 network greatly reduces ac ripple, it has little effect on dc. You should recall that an inductor offers no reactance to dc. The only opposition to current flow is the resistance of the wire in the choke. Generally, this resistance is very low and the dc voltage drop across the coil is minimal.

Aside from the voltage divider effect, the inductor improves filtering by resisting changes in the magnitude of the current flowing through it. Consequently, when the inductor is placed in series with the load, it maintains steady current. In turn, this helps the voltage across the load remain constant when size of components is a factor.

The *LC* filter provides good filtering action over a wide range of currents. The capacitor filters best when the load is drawing little current. Thus the capacitor discharges very slowly and the output voltage remains almost constant. On the other hand, the inductor filters best when the current is highest. The complementary nature of these two components ensures that good filtering will occur over a wide range of currents.

Failure Analysis of the *LC* Capacitor-Input Filter

Shunt capacitors are subject to open circuits, short circuits, and excessive leakage; series inductors are subject to open windings and occasionally short-circuited turns or a short circuit to the core.

The input capacitor C_1 has the greatest pulsating voltage applied to it, is the most susceptible to voltage surges, and has a generally higher average voltage applied. As a result, the input capacitor is frequently subject to voltage breakdown and short-circuiting. The output capacitor C_2 is not as susceptible to voltage surges because of the series protection offered by the series inductor L_1, but the capacitor can become open, leaky, or short-circuited.

A short-circuited capacitor, an open filter choke, or a choke winding which is short-circuited to the core, results in a no-output indication. A short-circuited capacitor, depending on the magnitude of the short, may cause a short-

circuited rectifier, transformer, or filter choke and may result in a blown fuse in the primary of the transformer. An open filter choke results in an abnormally high dc voltage at the input to the filter and no voltage at the output of the filter. A leaky or open capacitor in the filter circuit results in a low dc output voltage. This condition is generally accompanied by an excessive ripple amplitude. Short-circuited turns in the winding of a filter choke reduce the effective inductance of the choke and decrease its filtering efficiency. As a result, the ripple amplitude increases.

LOAD REGULATION

A commonly used figure of merit for a power supply is its *percent of regulation*. The percent of regulation gives us an indication of how much the output voltage changes over a range of load resistance values. The percent of regulation aids in determining the type of load regulation needed. Percent of regulation (PR) is determined by the equation

$$\frac{V_{\text{no load}} - V_{\text{full load}}}{V_{\text{full load}}} \times 100$$

This equation compares the change in output voltage at the two loading extremes to the voltage produced at full loading. For example, assume that a power supply produces 30 V when the load current is zero. If the output voltage drops to 20 V when full load current flows, the percent of regulation is

$$\text{PR} = \frac{V_{\text{no load}} - V_{\text{full load}}}{V_{\text{full load}}} = \frac{30 - 20}{20}$$

$$= \frac{10}{20} \times 100 = 50\%$$

Ideally, the output voltage should not change over the full range of operation. That is, a 30-V power supply should produce 30 V at no load, at full load, and at all points in between. In this case, the percent of regulation would be

$$\text{PR} = \frac{V_{\text{no load}} - V_{\text{full load}}}{V_{\text{full load}}} = \frac{30 - 30}{30} = \frac{0}{30} 100 = 0\%$$

Thus 0 percent load regulation is the ideal situation. It means that the output voltage is constant under all load conditions. While you should strive for 0 percent load regulation, in practical circuits you must settle for something less ideal. Even so, by using a voltage regulator, you can hold the percent of regulation to a very low value.

REGULATORS

You should know that the output of a power supply varies with changes in input voltage and circuit load current requirements. Because electronic equipment requires operating voltages and currents that must remain constant, some form of regulation is necessary. Circuits which maintain power supply voltages or current outputs within specified limits, or tolerances, are called *regulators*. They are designated as dc voltage or dc current regulators, depending on their specific applications.

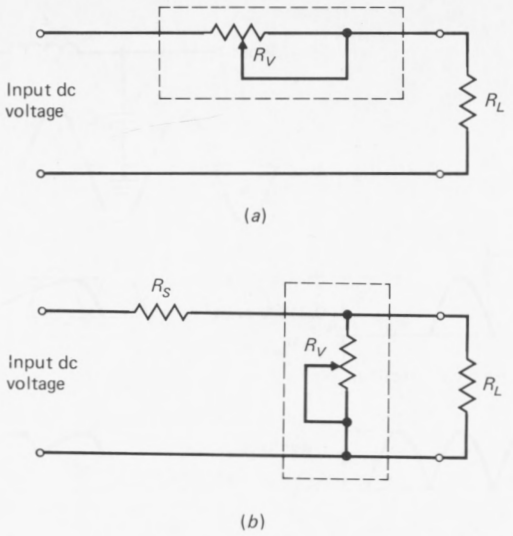


Fig. 6-7. Simple series (*a*) and shunt (*b*) regulators.

Voltage Regulators

There are two basic types of voltage regulators. Basic voltage regulators are classified as either *series* or *shunt*, depending on the location(s) or position(s) of the regulating element(s) in relation to the circuit load resistance. Figure 6-7 illustrates those two basic types of voltage regulators. In actual practice the circuitry of regulating devices may be quite complex. Broken lines have been used in the figure to highlight the difference between the series and shunt regulators.

The schematic drawing in Fig. 6-7*a* is that of a series regulator. It is called a *series regulator* because the regulating device is connected in series with the load resistance. The schematic drawing in Fig. 6-7*b* represents a shunt regulator. It is called a shunt-type regulator because the regulating device is connected in parallel with the load resistance. Figure 6-8 illustrates the principle of series voltage regulation. As you study the figure, notice that the regulator is in series with the load resistance R_L, thereby forming a voltage divider. Whenever the load current changes, the voltage across the load resistor also changes. Thus the value

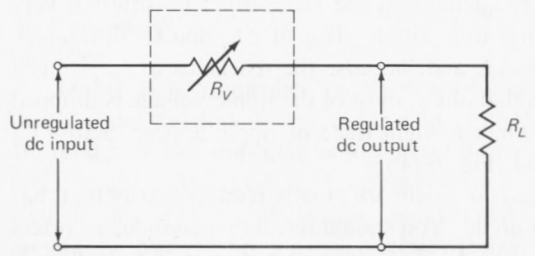


Fig. 6-8. Simple series voltage regulator.

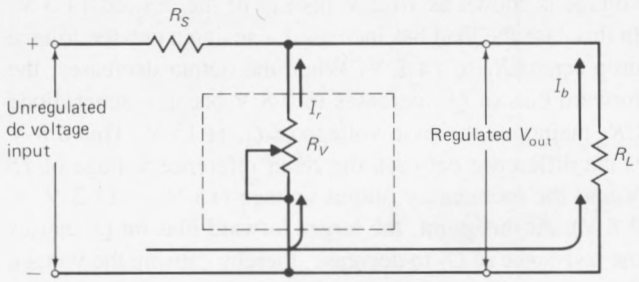


Fig. 6-9. Simple shunt voltage regulator.

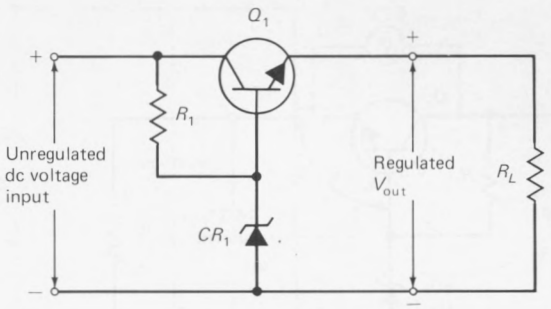


Fig. 6-10. Series voltage regulator circuit.

of the voltage regulator R_V must also change in order to maintain the correct output voltage value.

In a shunt regulator (Fig. 6-9) output voltage regulation is determined by the current through the parallel resistance of the regulating device R_V, the load resistance R_L, and the series resistor R_S. For now, assume that the circuit is operating under normal conditions, the input is 120 V dc, and the desired regulated output is 100 V dc. For a 100-V output to be maintained, 20 V must be dropped across the series resistor R_S. If you assume that the value of R_S is 2 Ω, you must have 10 A of current across R_V and R_L. (Remember that $V = I \times R$.) If the values of the resistance of R_V and R_L are equal, 5 A of current will flow through each resistance (R_V and R_L).

Now, if the load resistance R_L increases, the current through R_L will decrease. For example, assume that the current through R_L is now 4 A and the total current across R_S is 9 A. With this drop in current, the voltage drop across R_S is 18 V; consequently, the output of the regulator has increased to 102 V. At this time, the regulating device R_V decreases in resistance, and 6 A of current flows through it. Thus the total current through R_S is once again 10 A (6 A across R_V; 4 A across R_L) and 20 V is dropped across R_S, causing the output to decrease back to 100 V. From this you can see that if the load resistance R_L increases, the regulating device resistance R_V decreases to compensate for the change.

Now consider the circuit when a decrease in load resistance takes place. When R_L decreases, the current through R_L subsequently increases to 6 A, causing a total of 11 A to flow through R_S, which then drops 22 V. As a result, the output is 98 V. However, the regulating device R_V senses this change and increases its resistance so that less current (4 A) flows through R_V. The total current again becomes 10 A, and the output is again 100 V.

From these examples, you should now understand that the shunt regulator maintains the desired output voltage first by sensing the current change in the parallel resistance of the circuit and then compensating for the change.

Again refer to the schematic diagram shown in Fig. 6-9 and consider how the voltage regulator operates to compensate for changes in input voltages. You know, of course, that the input voltage may vary and that any variation must be compensated for by the regulating device. If an *increase in input voltage occurs,* the resistance of R_V automatically decreases to maintain the correct voltage division between R_V and R_S. You should see, therefore, that the regulator operates in the opposite way to compensate for a *decrease in input voltage.*

So far only voltage regulators that use variable *resistors* have been explained; however, this type of regulation has limitations. Obviously, the variable resistor cannot be adjusted rapidly enough to compensate for frequent fluctuations in voltages. Since input voltages fluctuate frequently and rapidly, the variable resistor is *not* a practical method for voltage regulation. A voltage regulator that operates continuously and automatically to regulate the output voltage without external manipulation is required for practical regulation.

The schematic for a typical series voltage regulator is shown in Fig. 6-10. Notice that this regulator has a transistor Q_1 in place of the variable resistor found in Fig. 6-8. Because the total load current passes through this transistor, it is sometimes called a "pass transistor." Other components which make up the circuit are the current limiting resistor R_1 and the zener diode CR_1.

A zener diode is a diode which blocks current until a specified voltage is applied. The specified voltage is called the *breakdown,* or *zener voltage.* Zener diodes are available with different zener voltages. When the zener voltage is reached, the zener diode conducts from its anode to its cathode (with the direction of the arrow).

In this voltage regulator, Q_1 has a constant voltage applied to its base. This voltage is often called the *reference voltage.* As changes in the circuit output voltage occur, they are sensed at the emitter of Q_1, producing a corresponding change in the forward bias of the transistor. In other words, Q_1 compensates by increasing or decreasing its resistance to change the circuit voltage division.

Now study Fig. 6-11. Voltages are shown to help you understand how the regulator operates. The zener used in this regulator is a 15-V zener. In this instance, the zener or breakdown voltage is 15 V. The zener establishes the value of the base voltage for Q_1. The output voltage will equal the zener voltage minus a 0.7-V drop across the forward-biased base-emitter junction of Q_1, or 14.3 V. Because the output voltage is 14.3 V, the voltage drop across Q_1 must be 5.7 V.

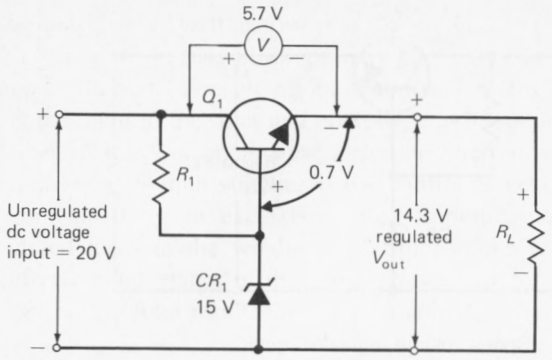


Fig. 6-11. Series voltage regulator circuit (with voltage).

Study Fig. 6-12*a* to understand what happens when the input voltage exceeds 20 V. Notice the input and output voltages of 20.1 and 14.4 V, respectively. The 14.4-V output voltage is a momentary deviation, or variation, from the required regulated output voltage of 14.3 and is the result of a rise in the input voltage to 20.1 V. Since the base voltage of Q_1 is held at 15 V by CR_1, the forward bias of Q_1 changes to 0.6 V. Because this bias voltage is *less than* the normal 0.7 V, the resistance of Q_1 increases, thereby increasing the voltage drop across the transistor to 5.8 V. This voltage drop restores the output voltage to 14.3 V. The entire cycle takes only a fraction of a second; therefore, the change is not readily measurable with standard test equipment.

Figure 6-12*b* is a schematic diagram for the same series voltage regulator with one significant difference. The output voltage is shown as 14.2 V instead of the desired 14.3 V. In this case the load has increased, causing a greater voltage drop across R_L to 14.2 V. When the output decreases, the forward bias of Q_1 increases to 0.8 V because zener diode CR_1 maintains the base voltage of Q_1 at 15 V. This 0.8 V is the difference between the zener reference voltage of 15 V and the momentary output voltage (15 V − 14.2 V = 0.8 V). At this point, the larger forward bias on Q_1 causes the resistance of Q_1 to decrease, thereby causing the voltage drop across Q_1 to return to 5.7 V. This then causes the output voltage to return to 14.3 V.

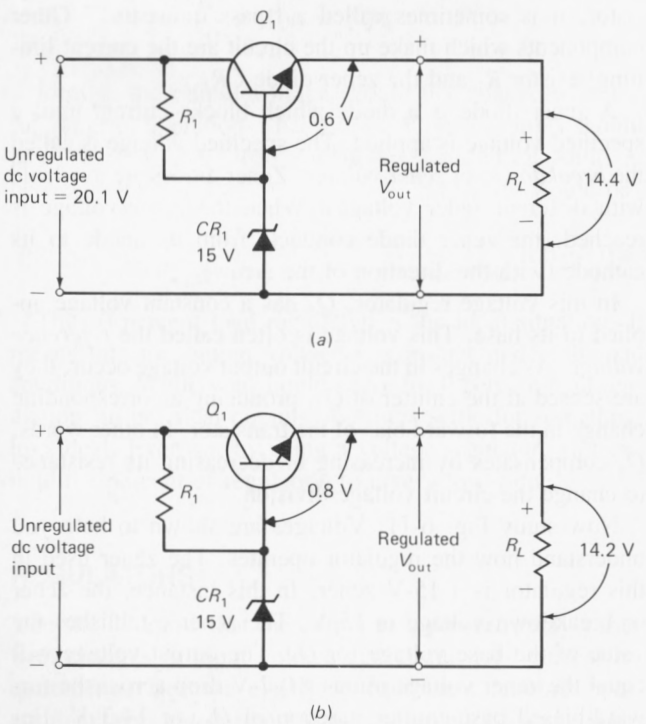


Fig. 6-12. Series voltage regulator circuit: (*a*) increased output; (*b*) decreased output.

The schematic shown in Fig. 6-13 is that of a shunt voltage regulator. Notice that Q_1 is in *parallel* with the load. Components of this circuit are identical with those of the series voltage regulator except for the addition of fixed resistor R_S. As you study the schematic, you will see that this resistor is connected in series with the output load resistance. The current-limiting resistor R_1 and zener diode CR_1 provide a constant reference voltage for the base-collector junction of Q_1. Notice that the bias of Q_1 is determined by the voltage drop across R_S and R_1. As you should know, the amount of forward bias across a transistor affects its total resistance. In this case, the voltage drop across R_S is the key to the total circuit operation.

Figure 6-14 is the schematic for a typical shunt-type regulator. Notice that the schematic is identical to the schematic shown in Fig. 6-13 except that voltages are shown to help you understand the functions of the various components. In the circuit shown, the voltage drop across the zener diode CR_1 remains constant at 5.6 V. This means that with a 20-V input voltage, the voltage drop across R_1 is 14.4 V. With a base-emitter voltage of 0.7 V, the output voltage is equal to the sum of the voltages across CR_1 and the voltage at the base-emitter junction of Q_1. In this example, with an output voltage of 6.3 V and a 20-V input voltage, the voltage drop across R_S equals 13.7 V. Study the schematic to understand fully how these voltages are developed. Pay close attention to the voltages shown.

Now refer to Fig. 6-15*a*. This figure shows the schematic diagram of the same shunt voltage regulator as that shown in Fig. 6-14 with an increased input voltage of 20.1 V. This increases the forward bias on Q_1 to 0.8 V. Recall that the voltage drop across CR_1 remains constant at 5.6 V. Since the output voltage is comprised of the zener voltage and

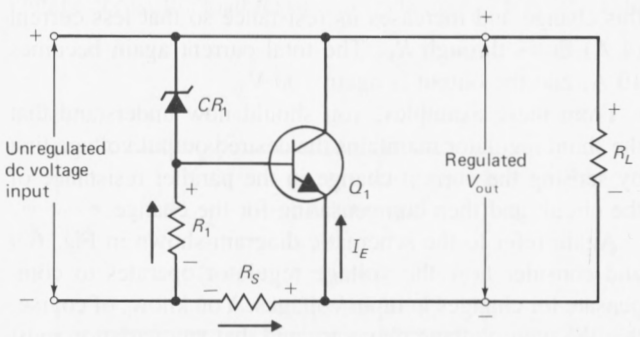


Fig. 6-13. Shunt voltage regulator circuit.

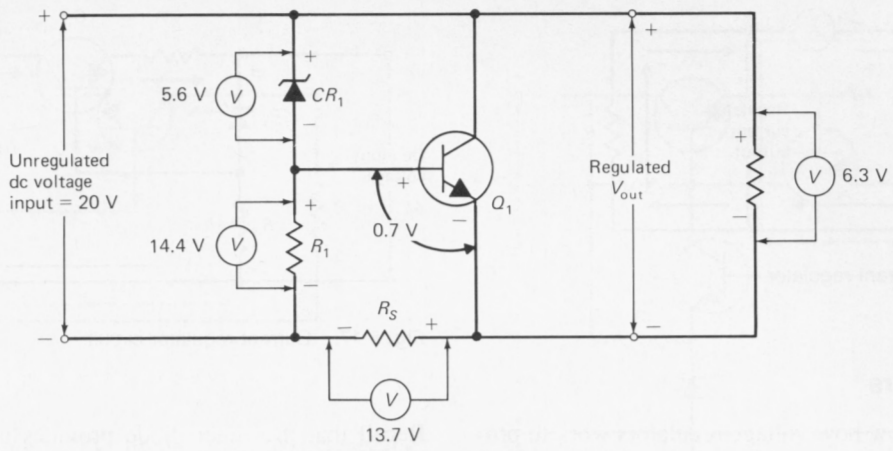


Fig. 6-14. Shunt voltage regulator circuit (with voltage).

the base-emitter voltage, the output voltage momentarily increases to 6.4 V. At this time, the increase in the forward bias of Q_1 lowers the resistance of the transistor, allowing more current to flow through it. Since this current must also pass through R_S, there is also an increase in the voltage drop across this resistor. The voltage drop across R_S is now 13.8 V; therefore, the output voltage is reduced to 6.3 V. Remember that this change takes place in a fraction of a second.

Study the schematic shown in Fig. 6-15*b*. Although this schematic is identical to the other shunt voltage schematics previously illustrated and discussed, the output voltage is different. The load current has increased, causing a *momentary* drop in voltage output to 6.2 V. Recall that the circuit was designed to ensure a constant output voltage of 6.3 V. Since the output voltage is less than that required, changes occur in the regulator to restore the output to 6.3 V. Because of the 0.1-V drop in the output voltage, the forward bias of Q_1 is now 0.6 V. This decrease in the forward bias increases the resistance of the transistor, thereby reducing the current flow through Q_1 by the same amount that the load current increased. The current flow through R_S returns to its normal value and restores the output voltage to 6.3 V.

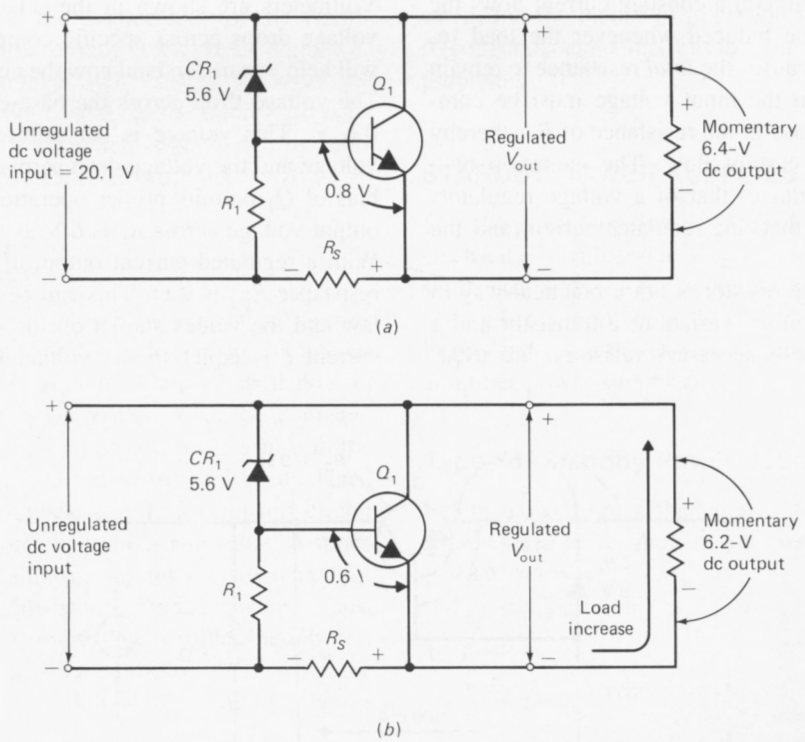


Fig. 6-15. Shunt voltage regulator circuit: (*a*) increase in output voltage; (*b*) decrease in output voltage.

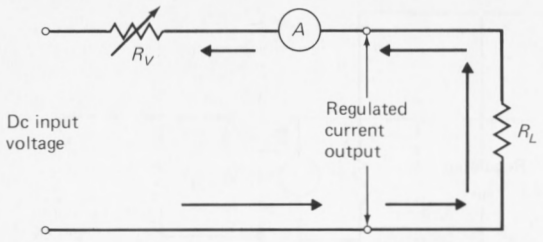


Fig. 6-16. Simple current regulator.

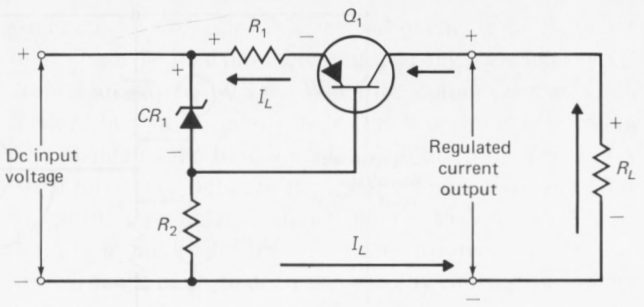


Fig. 6-17. Current regulator circuit.

Current Regulators

You should now know how voltage regulators work to provide constant output voltages. In some circuits it may be necessary to regulate the current output. The circuitry which provides a constant current output is called a *constant current regulator* or just *current regulator*. The schematic shown in Fig. 6-16 is a simplified schematic for a current regulator. The variable resistor shown on the schematic is used to illustrate the concept of current regulation. You should know from your study of voltage regulators that a variable resistor does not respond quickly enough to compensate for the changes. Notice that an ammeter has been included in this circuit to indicate that the circuit shown is that of a current regulator. When the circuit functions properly, the current reading of the ammeter remains constant. In this case the variable resistor R_V compensates for changes in the load or dc input voltage. Adequate current regulation results in the loss of voltage regulation. Studying the schematic shown, you should recall that any increase in load resistance causes a drop in current. To maintain a constant current flow, the resistance of R_V must be reduced whenever the load resistance increases. This causes the *total* resistance to remain constant. An increase in the input voltage must be compensated for by an increase in the resistance of R_V, thereby maintaining a constant current flow. The operation of a current regulator is similar to that of a voltage regulator. The basic difference is that one regulates current and the other regulates voltage.

Since use of a variable resistor is not a practical way to control current fluctuation, or variation, a transistor and a zener diode, together with necessary resistors, are used. Recall that the zener diode provides a constant reference voltage. The schematic shown in Fig. 6-17 is that of a current regulator circuit. Except for the addition of R_1, the circuit shown in the figure is similar to that of a series voltage regulator. The resistor is connected in series with the load and senses any current changes in the load. Notice the voltage drop across R_1 and the negative voltage polarity applied to the emitter of Q_1. The voltage polarity is a result of current flowing through R_1, and this negative voltage opposes the forward bias for Q_1; however, since the regulated voltage across CR_1 has an opposite polarity, the actual bias of the transistor is the difference between the two voltages. Therefore, you should see that the purpose of R_2 is to function as a current-limiting resistor for the zener diode.

The purpose of a current regulator is to provide a constant current regardless of changes in the input voltage or load current. The schematic shown in Fig. 6-18 is that of a circuit designed to provide a constant current of 400 mA. Voltmeters are shown in the schematic to emphasize the voltage drops across specific components. These voltages will help you understand how the current regulator operates. The voltage drop across the base-emitter junction of Q_1 is 0.6 V. This voltage is the difference between the zener voltage and the voltage drop across R_1. The 0.6-V forward bias of Q_1 permits proper operation of the transistor. The output voltage across R_L is 6 V as shown by the voltmeter. With a regulated current output of 400 mA, the transistor resistance R_{Q1} is 9 Ω. This can be proved by using Ohm's law and the values shown on the schematic. In this case, current I is equal to the voltage drop V divided by the

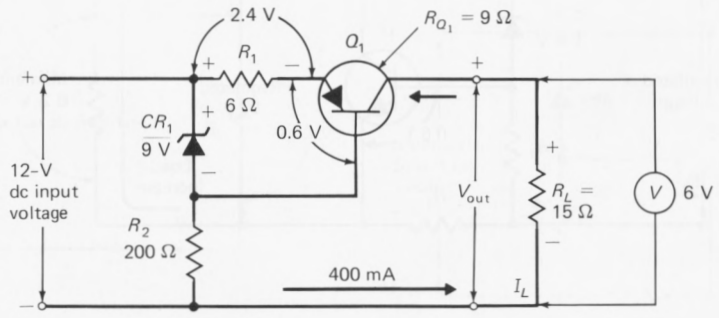


Fig. 6-18. Current regulator circuit (with values).

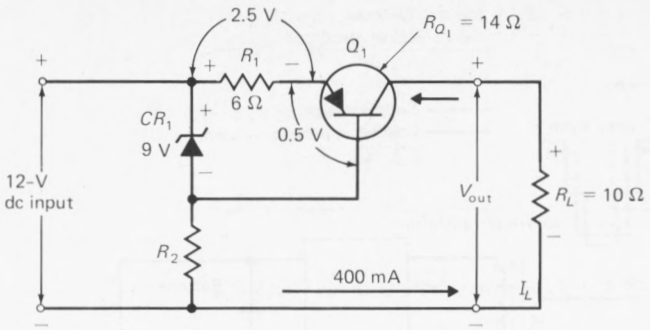


Fig. 6-19. Current regulator (with a decrease in R_L).

resistance R. Therefore, 12 V divided by 30 Ω equals 0.4 A, or 400 mA.

Since you are familiar with the basic current regulating circuitry, let us examine in detail how the various components work to maintain the constant 400-mA output. Refer to the schematic shown in Fig. 6-19. Remember that a decrease in load resistance causes a corresponding increase in current flow. In the example shown, the load resistance R_L has dropped from 15 to 10 Ω. This results in a larger voltage drop across R_1 because of the increased current flow. The voltage drop has increased from 2.4 to 2.5 V. Of course, the voltage drop across CR_1 remains constant at 9 V due to its regulating ability. Because of the increased voltage drop across R_1, the forward bias on Q_1 is now 0.5 V. Since the forward bias of Q_1 has decreased, the resistance of the transistor increases from 9 to 14 Ω. Notice that the 5-Ω increase in resistance across the transistor corresponds to the 5-Ω decrease in the load resistance. Thus the total resistance around the outside loop of the circuit remains constant. Since the circuit is a current regulator, you know that output voltages will vary as the regulator maintains a constant current output. In the figure, the voltage output is reduced to 4 V, which is computed by multiplying current I times resistance R (400 mA × 10 Ω = 4 V).

Short-Circuit Protection

The main disadvantage of a series regulator is that the pass transistor is in series with the load. If a short circuit develops in the load, a large amount of current will flow in the regulator circuit. The pass transistor can be damaged by this excessive current flow. You can place a fuse in the circuit, but in many cases the transistor will be damaged before the fuse blows. The best way to protect this circuit is to limit the current automatically to a safe value. A series regulator with a current-limiting circuit is shown in Fig. 6-20. For a silicon NPN transistor to conduct, the base must be between 0.6 and 0.7 V more positive than the emitter. Resistor R_4 will develop a voltage drop of 0.6 V when the load current reaches 600 mA. This is illustrated by Ohm's law:

$$I = \frac{V}{R} = \frac{0.6\text{ V}}{1\ \Omega} = 0.6\text{ A or }600\text{ mA}$$

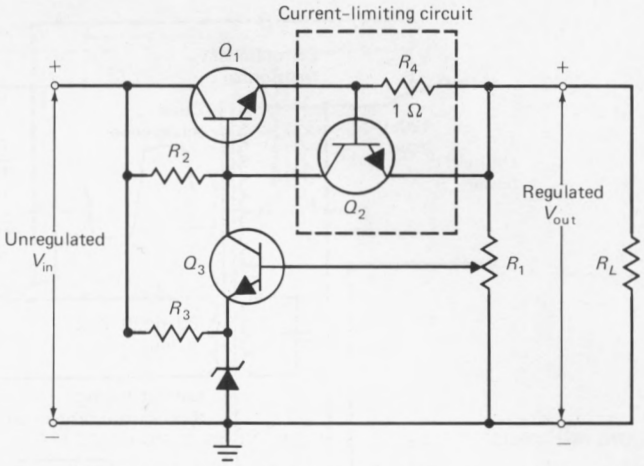


Fig. 6-20. Series regulator with current limiting.

When the load current is below 600 mA, the base-emitter voltage on Q_2 is not high enough to allow Q_2 to conduct. With Q_2 cut off, the circuit acts like a series regulator.

When the load current increases above 600 mA, the voltage drop across R_4 increases to more than 0.6 V. This causes Q_2 to conduct through resistor R_2, thereby decreasing the voltage on the base of pass transistor Q_1. This action causes Q_1 to conduct less. Therefore, the current cannot increase above 600 to 700 mA.

By increasing the value of R_4, you can limit the current to almost any value. For example, a 100-Ω resistor develops a voltage drop of 0.6 V at 6 mA of current. You may encounter current-limiting circuits that are more sophisticated, but the theory of operation is always the same. So, if you understand this circuit, the others should pose no problems.

STANDBY POWER SUPPLIES

Standby power supplies are needed because utility-supplied electricity is vulnerable to power interruptions. Some are short, lasting only a few seconds; others are lengthy outages lasting for several hours. Regardless of the cause, all result in power loss to the transformers supplying voltage to the amplifier power supplies.

Types of Standby Power Supplies

Let us now discuss the various types of standby power supplies available, their design approaches, and most important, reliability. There are three basic types of standby power supplies available:

1. *Type A*—has a power (ferroresonant) transformer with a separate inverter-transformer with either mechanical or electronic switching. Figure 6-21 shows the schematic of a type A standby power supply. The inverter is a device that changes the standby battery dc voltage to an ac voltage and is used when the input voltage to

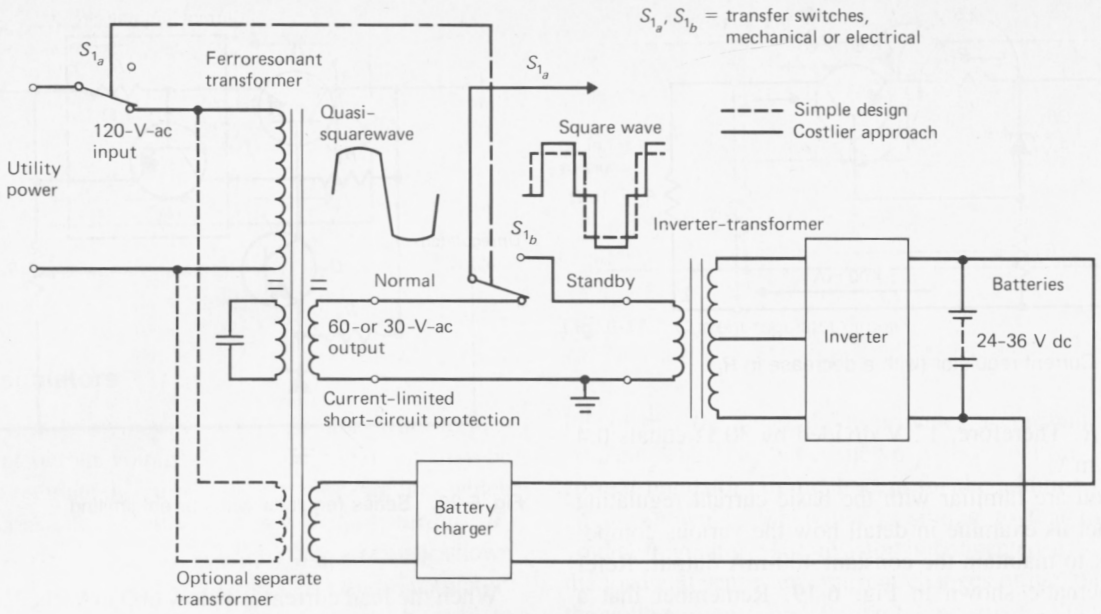


Fig. 6-21. Type A standby power supply circuit (*Alpha Technologies, Inc.*).

the power transformer is lost. This ac voltage is then used to power the amplifier power supplies.

2. *Type B*—has a single power transformer used for both normal and inverter operation. Figure 6-22 shows the schematic of a type B standby power supply.
3. *Type C*—has an inverter that runs continuously. Figure 6-23 shows the diagram of a type C standby power supply.

Standby Power Supply Design Features

Ferroresonant transformers are current-limiting devices that provide both line and load regulation. The unique feature of this transformer is the resonant circuit formed by the additional winding and a capacitor. This resonant circuit is located below the primary winding and saturates the secondary portion of the transformer on voltage surges.

Another important design feature is the amount of operating time available from the batteries. If a two-battery power supply is used, the average voltage during discharge is about 22 V, which would allow about 1.4 h of service. A three-battery power supply would supply 34 V during discharge and furnish about 2.4 h of continuous service.

Figure 6-24 shows a typical standby power supply that supplies either 30 or 60 V ac to amplifier power supplies. This standby power supply consists of a transformer, battery charger, inverter, and a line-transfer switch.

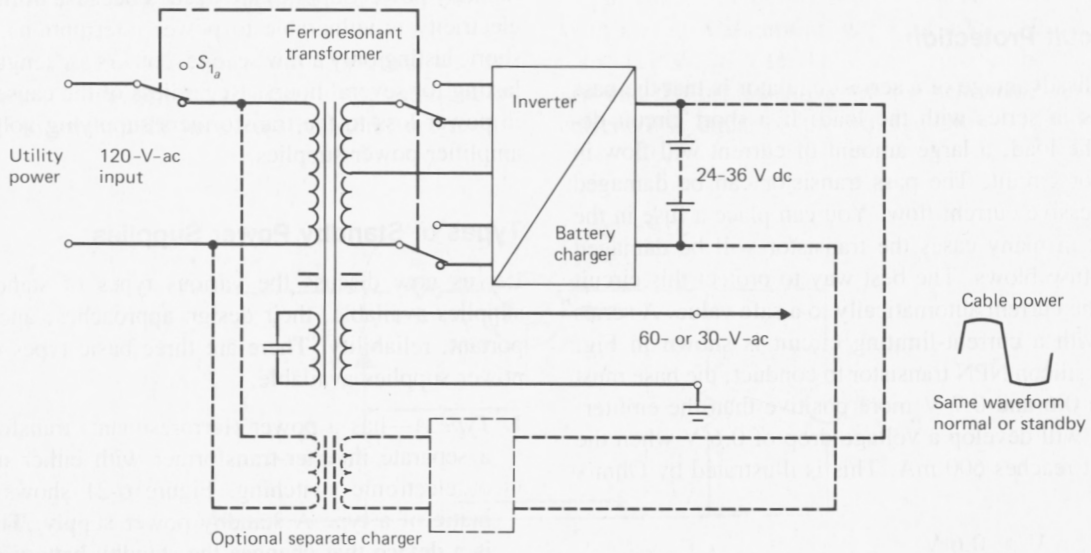


Fig. 6-22. Type B standby power supply circuit (*Alpha Technologies, Inc.*).

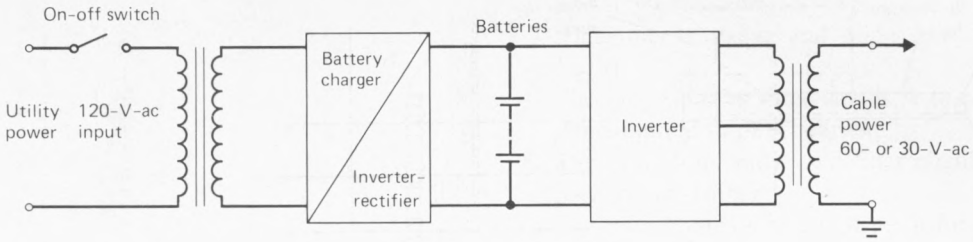


Fig. 6-23. Type C standby power supply circuit (*Alpha Technologies, Inc.*).

Theory of Operation

During normal operation, electrical power from the pole is connected to the primary of the transformer. The output of this transformer (either 30 or 60 VAC) is fed through the coaxial cable to each amplifier, where the voltage is used as the input to the amplifier power supply. The output of the power supply of the amplifier is used to power the amplifier circuits.

The purpose of the charger is to maintain a constant battery voltage that may be used during a power blackout.

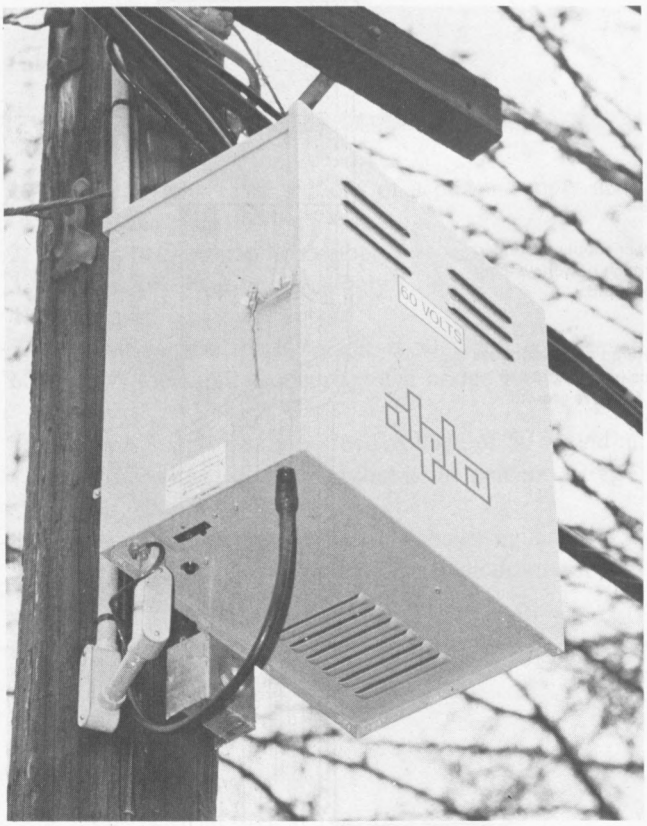


Fig. 6-24. Standby power supply housing (*Alpha Technologies, Inc.*).

When a power failure occurs, a monitor senses the drop of voltage and activates the line-transfer switch. The switch connects the battery powered inverter to the transformer, at the same time providing isolation from the power line. To ensure uninterrupted service, transfer takes place in less than one cycle. When power returns, the standby power supply reverts back to furnishing power to the amplifier from the secondary of the transformer. At the same time the battery charger begins to recharge the batteries.

Maintenance

Maintenance of the standby power supply is one of the most crucial jobs in obtaining trouble-free operation of the plant. A well-designed standby power supply will require a minimum of checkups, but checkups *are* necessary, particularly for wet-cell batteries. The quickest and simplest check of a battery is the voltmeter check. This check is made after removing one terminal connection and measuring across the two terminals. The voltage should be approximately 13 V. On wet cells, the electrolyte level should be checked. The terminal connections on all types of batteries should be tight and free from corrosion; any corrosion can be removed with a baking soda solution. After reconnecting the terminal, it should be coated with a corrosion-retardant spray. Maintenance intervals can range from every 2 months to once a year depending on the quality of the supply.

Figure 6-25 shows the specifications for mounting of a standby power supply above the strand cable level. Strand cable is a ¼-in. cable used to support coaxial cable in aerial construction. Figure 6-26 shows the specifications for a pole-mounted standby power supply below strand level. Figure 6-27 illustrates the construction practice for mounting a standby power supply to serve cable systems that utilize underground cable construction.

SUMMARY

1. The four basic sections of a power supply are the transformer, the rectifier, the filter, and the regulator.
2. The three types of rectifier circuits used in power supplies are the (*a*) half-wave, (*b*) the full-wave, and (*c*) the bridge.

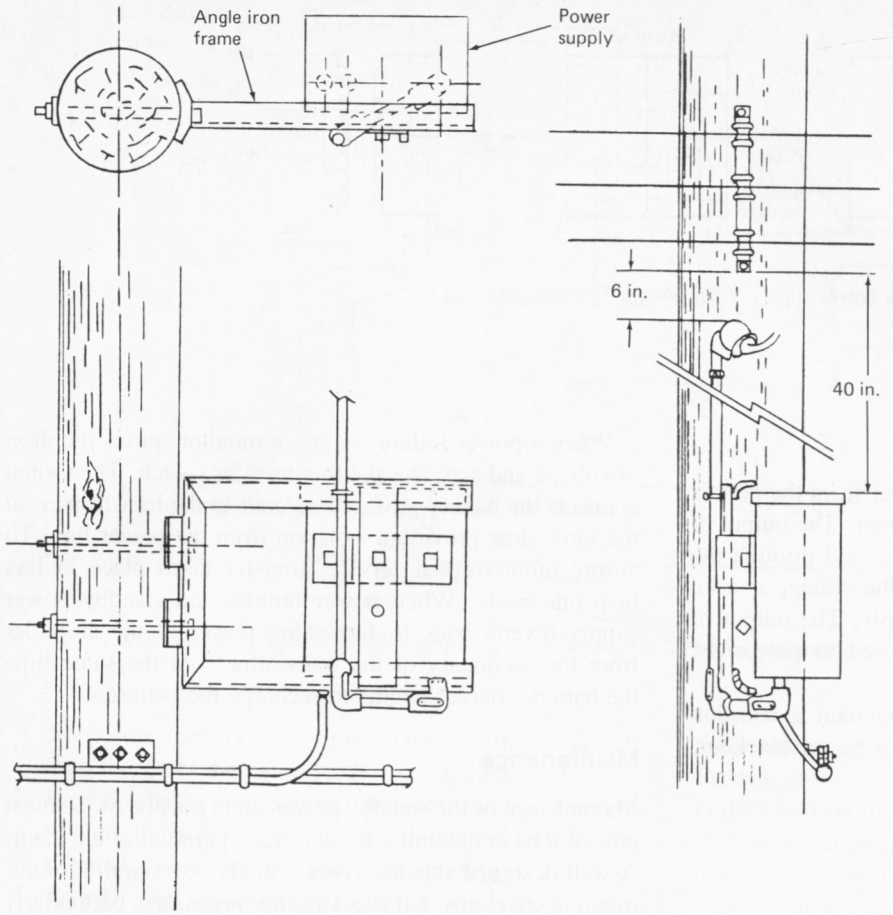


Fig. 6-25. Standby power supply mounted above the strand cable.

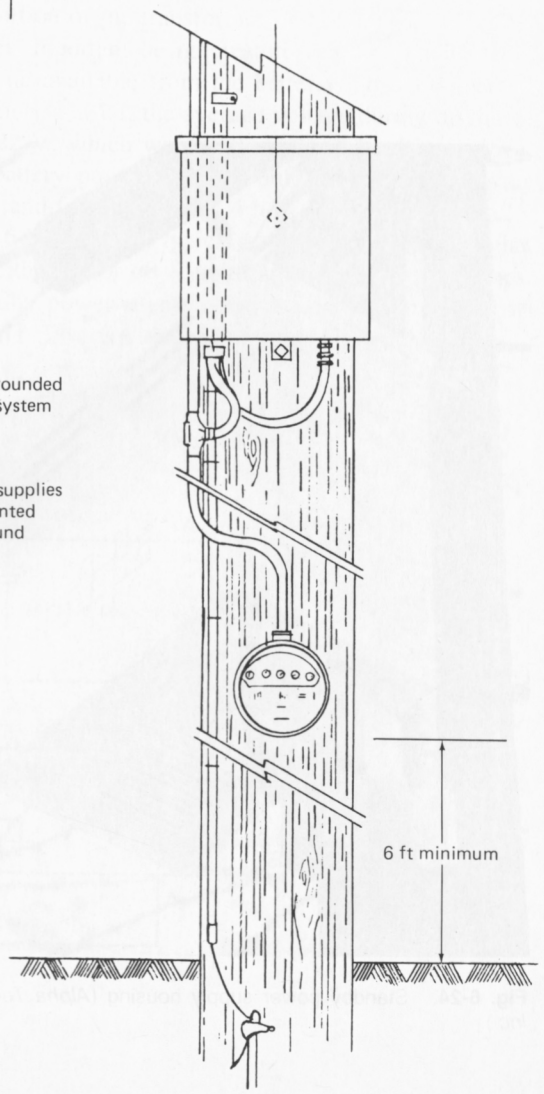

NOTES:
1. Power supply grounded through power system to ground.
2. Metered power supplies usually are mounted 12 ft above ground level.
6 ft minimum

Fig. 6-26. Standby power supply mounted below the strand cable.

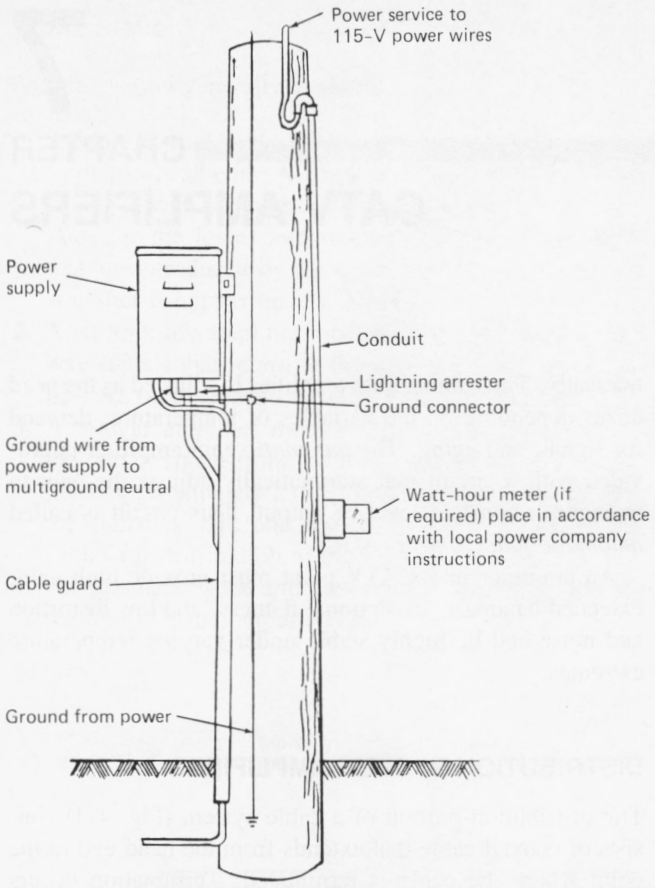


Fig. 6-27. Mounting of a standby power supply for buried-cable use.

3. The ripple frequency of a half-wave rectifier is 60 Hz, while the full-wave and bridge rectifier circuits are 120 Hz.
4. The purpose of a filter circuit is to reduce pulsating direct current to direct current.
5. The most commonly used filter circuit is the *LC* capacitive input filter.
6. The most common figure of merit for a power supply is its percent of regulation.
7. Power supply regulators fall into two categories, voltage regulators and current regulators.
8. The two basic types of voltage regulators are the series and the shunt types.
9. The purpose of a current regulator is to provide a constant current regardless of changes in input voltage.
10. The incorporation of a current-limiting circuit into a series regulator provides short-circuit protection.
11. Standby power supplies are needed whenever a power failure occurs.
12. Standby power supplies furnish either 30 or 60 V to the power supplies of amplifiers.

REVIEW QUESTIONS

1. Name the four basic sections of a power supply and explain the purpose of each.
2. Draw a half-wave power supply.
3. Draw a full-wave power supply.
4. Draw a bridge power supply.
5. To what value of peak voltage is 50 V rms equal?
6. What is the ripple frequency of a bridge rectifier circuit?
7. A power supply has a no-load voltage of 50 V and a full-load voltage of 40 V. What is the percent of regulation for this power supply?
8. What are the two basic types of voltage regulators?
9. What is the purpose of using a zener diode in a regulator circuit?
10. What type of circuit is used to provide short-circuit protection for the pass transistor of a series regulator?
11. What is the purpose of a standby power supply in a CATV system?
12. What is the function of the inverter in the standby power supply?
13. What are the output voltages of a standby power supply?
14. Explain the sequence of events that occur in the standby power supply when a power failure is experienced.
15. What is the simplest and quickest method of checking a battery?

7
CHAPTER
CATV AMPLIFIERS

INTRODUCTION

In this chapter you will learn about:

1. The four types of amplifier stations
2. The various forms of distortion found in CATV amplifiers
3. The function of each amplifier type
4. The component parts of a trunk amplifier station
5. The theory of operation of the various modules that make up a trunk amplifier station
6. The specifications of a typical trunk amplifier station
7. The cable system as a whole

The principal active device used within the distribution system of a CATV plant is the amplifier. The function of the amplifier is to amplify the weak signals on the cable. An amplifier is contained in a housing having an access cover that is hinged on one side. Bolts are used to hold the cover closed. The cover contains a sealing ring to seal moisture out and a metallic braid to prevent RF leakage. The size of the housing will vary with the size of the equipment enclosed. Some housings are as long as 18 in., as wide as 10 in., and as thick as 5 in.

The housings have mounting clamps for attachment to a supporting cable for use in aerial construction. Openings are made available for entrance into the housing by cables and are closed off with a seal and plug if not used. Inside the cover, provisions are made for charts and other information pertaining to the proper operation of the equipment. Some housings have special shields or shades for use in particularly hot environments. Usually special chemicals are placed in the housing to prevent excess moisture from harming the critical components. These protective agents may be silica gel or a similar dry desiccant.

Inside the housing are the amplifiers, the amplifier power supply, cable equalizers, fixed attenuators, filters, fuses, circuit breakers, and test points for both power and signals. There are several modules for the different functions. A module is a packaged assembly of electronic components that can be plugged into or removed from a master assembly. Each unit has adjustable controls used to set the equipment at the proper operating levels. Figure 7-1 shows a CATV trunk station with its full complement of modules and the location of the various controls.

Amplifier gain may be varied either manually or automatically. The *manual* gain amplifier is adjusted as the need arises depending on the variables of temperature, demand for signal, and aging. The *automatic* gain amplifier is provided with a circuit that automatically adjusts the gain to maintain a constant level of output. This circuit is called *automatic gain control* (AGC).

An amplifier in a CATV plant must provide high gain, extended bandpass, exceptional flatness, and low distortion and noise and be highly stable under varying temperature extremes.

DISTRIBUTION SYSTEM AMPLIFIERS

The distribution portion of a cable system (Fig. 1-4) consists of coaxial cable that extends from the head-end to the point where the cable is terminated. Termination occurs after the last amplifier in both the trunk and the feeder cable lines. Periodically the signals on both the trunk and the feeder lines must be amplified to overcome the cable losses. The devices that compensate for these losses are the distribution system amplifiers. An amplifier station is a housing that contains all the components needed to amplify, filter, and route the signals on the cable. There are four types of amplifier stations in a distribution system.

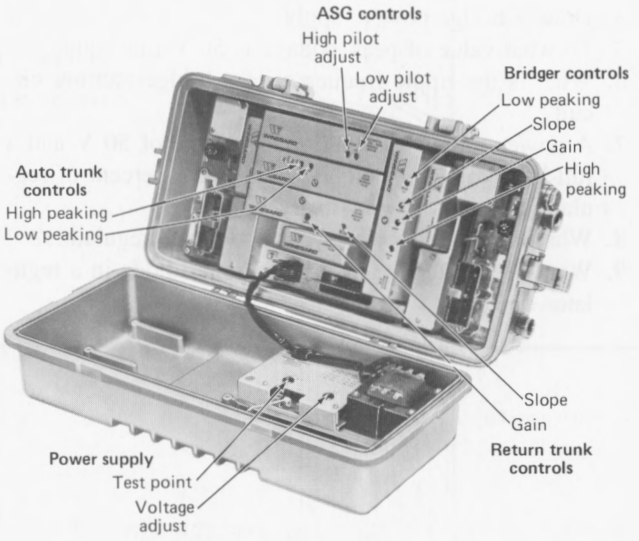


Fig. 7-1. CATV trunk station (*Winegard Co.*)

Trunk Station

A trunk station generally contains:

1. A forward trunk amplifier module to amplify the signals from the head-end. A trunk amplifier is basically an amplifier with low noise characteristics which compensates for the losses and frequency response variations that are introduced by the cable itself. The gain of this amplifier is approximately 20 dB.
2. A return trunk amplifier module for amplifying the two-way signals that return to the head-end. The return signals are on a subband frequency of 5 to 30 MHz.
3. A bridger amplifier module that removes a portion of the output signal from the trunk amplifier and reamplifies it approximately 25 dB. From the bridger amplifier, the signal is split and fed to as many as four feeder cables for distribution to the community.
4. An automatic slope and gain (ASG) module to stabilize the levels of the output signals.

Trunk stations are generally placed about 1500 ft apart on the distribution trunk cable. Figures 7-2 and 7-3 show a complete trunk station.

Intermediate Bridger Station

The intermediate bridger station is a separate bridger amplifier that is used in those instances where there is no need to amplify forward signals on the trunk, but where up to four feeder lines must be provided for. Provisions for amplifying return signals may also be included depending on the requirements of the system. Figures 7-4 and 7-5 show a typical intermediate bridger station.

Terminating Bridger Station

A terminating bridger station is located at the end of a trunk line and provides termination as well as amplification for up to four feeder lines. Amplification for return signals may also be provided. Figures 7-6 and 7-7 show a typical terminating bridger station.

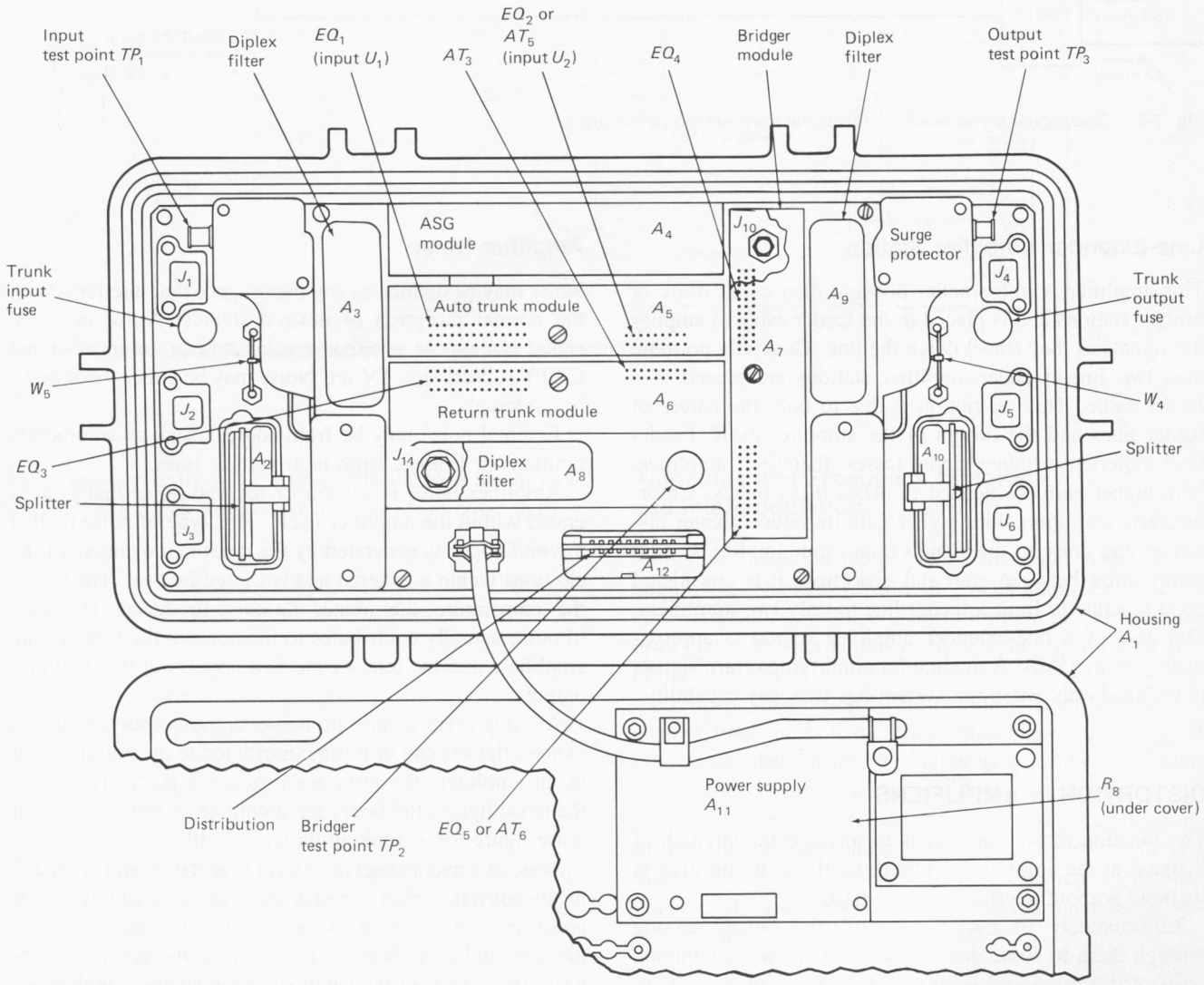


Fig. 7-2. Trunk station module complement (*Winegard Co.*).

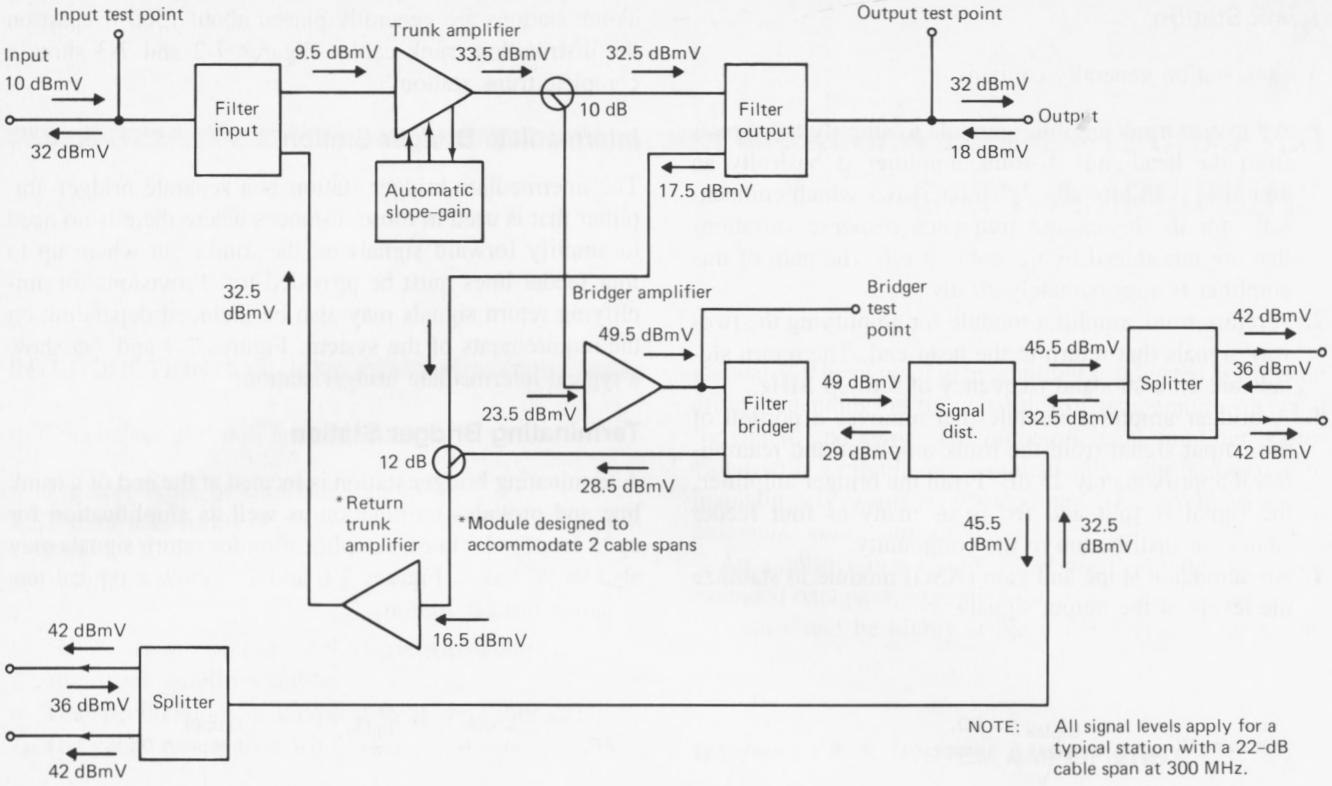


Fig. 7-3. Operational signal levels, bidirectional trunk station (*Winegard Co.*).

Line-Extender Amplifier Station

This amplifier is in a smaller housing than either trunk or bridger stations and is placed in the feeder cable to amplify the signals as they travel down the line. Generally no more than two line-extender amplifier stations are placed in a feeder cable. This restriction is due to both the nature of feeder lines and the design of the amplifier itself. Feeder lines experience higher signal losses; therefore, amplifiers with higher gain are needed to offset these losses. Unfortunately, amplifiers with higher gain introduce greater distortion and noise to the signals than trunk amplifiers. As a compromise between gain and distortion, it is considered good practice to limit a feeder line to only two amplifiers. The gain of a line-extender amplifier station is approximately 30 to 35 dB. A module for amplifying return signals is included only when the system has two-way capability.

DISTORTION IN AMPLIFIERS

The function of an amplifier is to increase the strength of a signal at the amplifier's output exactly as it appeared at its input without altering its waveshape.

Unfortunately all amplifiers distort the signals passing through them to some degree. Some of the more common types of distortion encountered in CATV amplifiers are described in the following paragraphs.

Amplifier Noise

Noise may be defined as any disturbance that interferes with the normal reception of desired signals. Noise in a TV signal can appear as either streaks, flashes, or snow on the CATV subscriber's TV set. Noise may be either "external" or "internal."

External noise may be from sources such as automobile ignitions or leakage from high-voltage lines.

Amplifier noise is a form of internal noise that is generated within the amplifier itself. This type of noise (called *thermal noise*) is generated by the random movement of the electrons within a material and is caused by heat. The higher the temperature, the greater the noise produced. This kind of noise actually contributes to the noise at the input of the amplifier, and the total of the two appears at the amplifier output.

All amplifiers contribute noise to the output signal. To express the amount of noise contributed to the output signal of an amplifier, the term *noise figure* is used. The lower the noise figure, the better the amplifier. A typical value of noise figure for a trunk amplifier is 7 dB.

Noise is a major concern to CATV operators and is present in all coaxial cables, passive devices, and amplifiers. A noise level of -59 dBmV is accepted as a base level by the cable industry. Noise in the subscriber's receiver results when the signal on the cable system contains a high noise level compared to a low video level. The relationship of

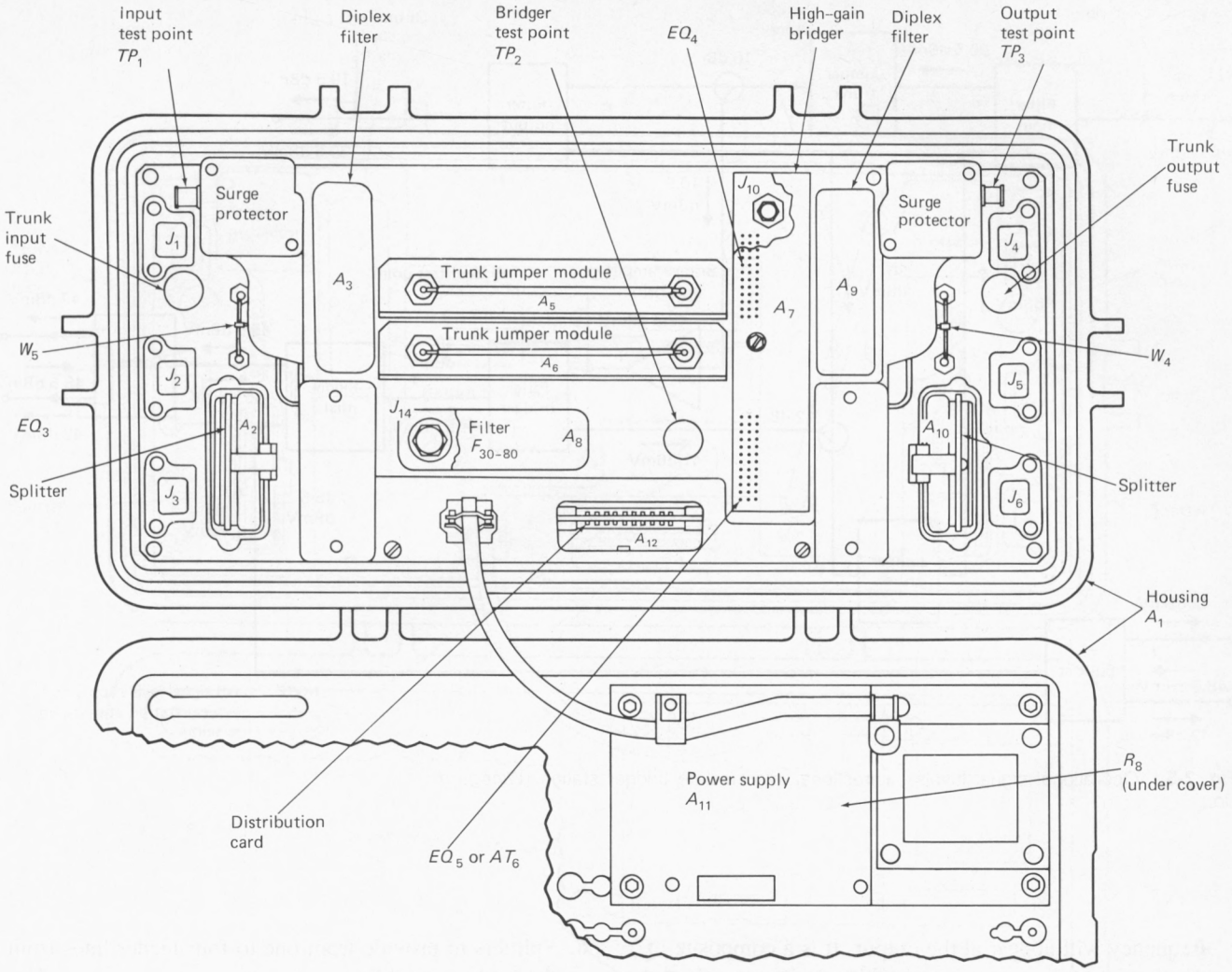


Fig. 7-4. Intermediate bridger station module complement (*Winegard Co.*).

the video level to the noise level is referred to as the *carrier-to-noise* ratio. The formula for the carrier-to-noise ratio is

$$\frac{C}{N} = S_{in} - NF + 59$$

where C/N = carrier-to-noise ratio
S_{in} = input signal level
59 = thermal noise value
NF = noise figure

For example, if the signal level at the input to an amplifier is 10 dBmV and the noise figure is 7 dB, then

$$\frac{C}{N} = 10 - 7 + 59 = 62 \text{ DB}$$

Amplitude and Frequency Distortion and Intermodulation

Amplitude distortion occurs when the input signal to the amplifier is changed (distorted) by the amplifier circuitry. An example of amplitude distortion might be the flattening of one or both alternations of the output signal by the amplifier.

Frequency distortion is the nonlinear amplification of a band of frequencies that causes some frequencies to be amplified more than others. In addition, some frequencies within the band may experience an additional phase shift.

Intermodulation Intermodulation (or Intermod) is a form of distortion where two or more carriers interact with each other to form a composite frequency called a *beat* frequency. The more common forms of intermodulation distortion found in CATV systems are:

1. Second-order distortion. If two different frequencies of the same amplitude are fed into an amplifier, only one

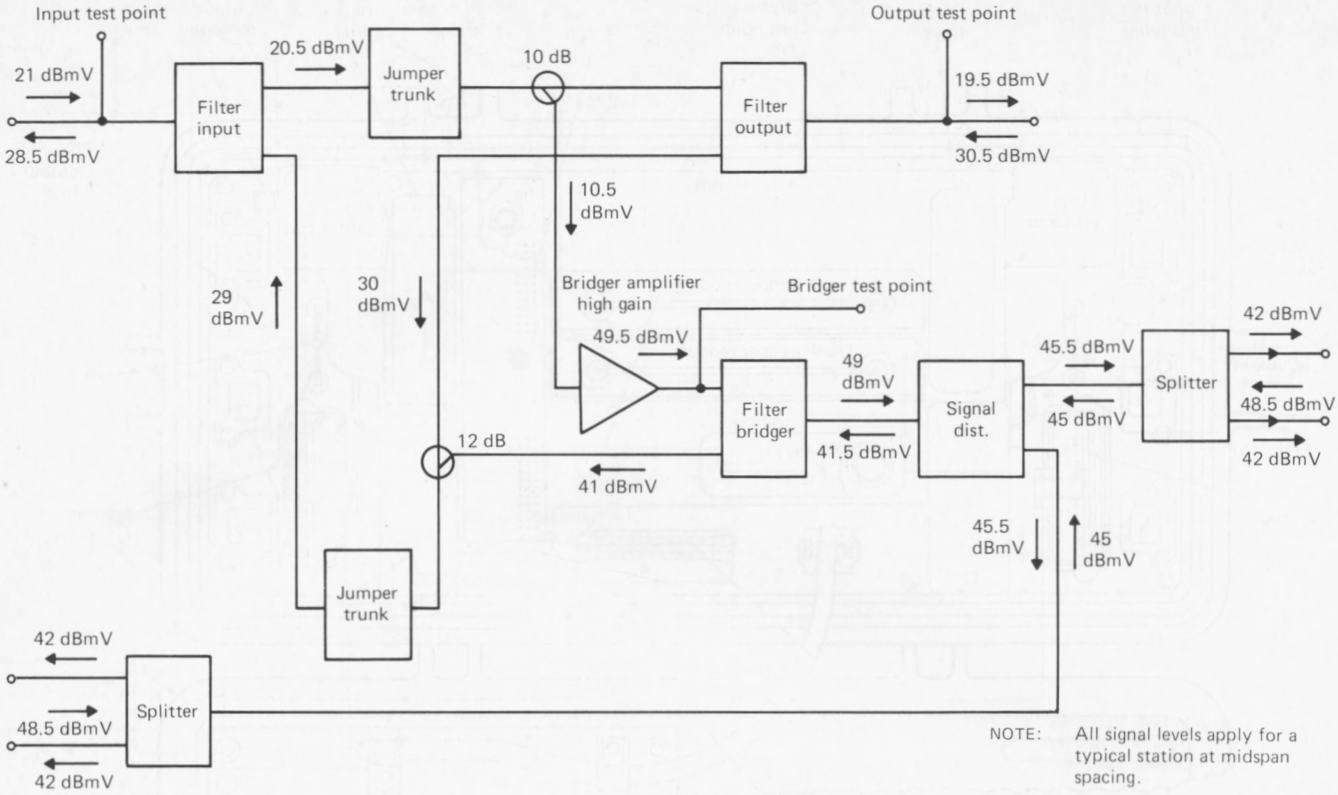


Fig. 7-5. Operational signal levels, bidirectional intermediate bridger station (*Winegard Co.*).

frequency will appear at the output. It is a composite of the two input frequencies and will contain not only the two original frequencies, but also the sum and difference frequencies.

2. Third-order distortion. Triple beat, one form of third-order distortion, is the mixing of three frequencies A, B, and C. The formula for triple beats is either $A + B - C = D$ or $2A - B = D$.
3. Composite triple beat. Composite triple beat results from the combined effect of a large number of triple beats caused by the amplification of many frequencies in a common amplifier.

COMPONENT PARTS OF AMPLIFIER STATIONS

Looking at Figs. 7-2, 7-4, and 7-6, we can see that many items are used to make up trunk stations. The items and their functions are:

1. Test points *TP* to measure both input and output signals and voltages
2. Filters to accept or reject bands of frequencies
3. Coaxial jumpers to join the input and output terminals of a module that is not utilized
4. Fuses to limit the amount of current flow
5. Jumpers W_4, W_5 to connect voltage to feeder lines
6. Splitters to provide from one to four feeder lines from the bridger amplifier
7. Distribution cards to connect the output of the bridger amplifier to the input of a splitter
8. Jacks *J* for both input and output coaxial lines
9. Forward trunk modules to amplify the signals coming from the head-end toward the subscriber (downstream signals)
10. Return trunk modules to amplify the signals coming from the subscriber toward the head-end (upstream signals)
11. Bridger modules to reamplify the signals coming from the trunk modules on their way to the feeder lines
12. Automatic slope and gain (ASG) modules to maintain the slope and gain of the signals at a preset level
13. A power supply to provide 24 V dc to the amplifier circuits
14. An input end plate to provide a connection between the input cable and the amplifier
15. An output end plate to provide a connection between the amplifier and the output cable
16. A base plate to accommodate the modules and provide connection to both end plates
17. A trunk jumper module to connect the input and output jacks of the trunk line when a trunk module is not needed

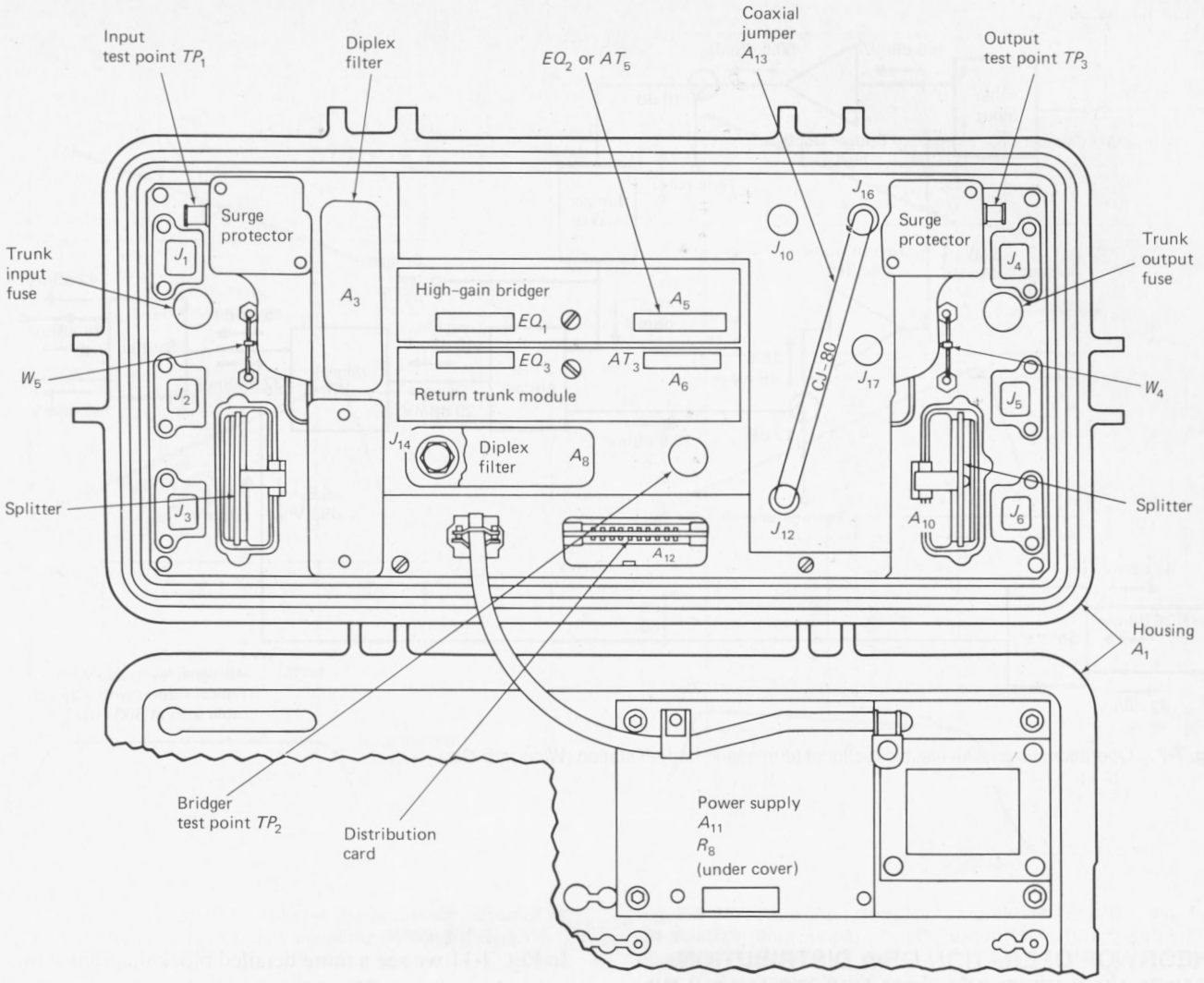


Fig. 7-6. Terminating bridger station module complement (*Winegard Co.*).

18. Potentiometer R_8 to adjust the power supply for an output of 24 V dc
19. Surge protector to protect the electronic circuits in CATV stations from most transients of high voltage and high current caused by lightning or other sources
20. Equalizer *EQ*, which plays an extremely important part in the operation of the CATV system
21. Attenuator pad *AT* to prevent amplifiers from operating close to the point of minimum gain

Regarding equalizers (item 20 above), characteristic cable losses at high frequencies (Fig. 7-8*a*) cause a tilt (nonlinear amplification) in the signal that is unacceptable without the opposite, corrective action of the equalizer (Fig. 7-8*b*). Attenuation in the equalizer decreases with increasing frequency to a minimum value referred to as *insertion loss*. The combination of cable and equalizer for equal decibel levels produces a flat loss (insertion loss + 1 dB) across the bandpass. Figure 7-8 does not illustrate changes in cable characteristics due to changes in temperature. Cable attentuation will vary directly with temperature (ca. 1.1 percent change for every 10°F change). In a practical situation (Fig. 7-9) the equalizer is selected to be 3 to 5 dB lower than an exact complement of cable losses. The resultant tilt in response is then compensated for by using the slope control of the amplifier.

Concerning attenuator pads (item 21 above), if an amplifier were set to operate near its point of minimum gain and the temperature of the system decreased (resulting in fewer cable losses), even lower gain would be required from the amplifier and a loss of signal level would result. Therefore, for best performance, an amplifier should be operated near its published gain value by inserting an attenuator pad. The value of the attenuator pad should be chosen to ensure that the amplifier station is operated at 3 to 4 dB down from its maximum gain value.

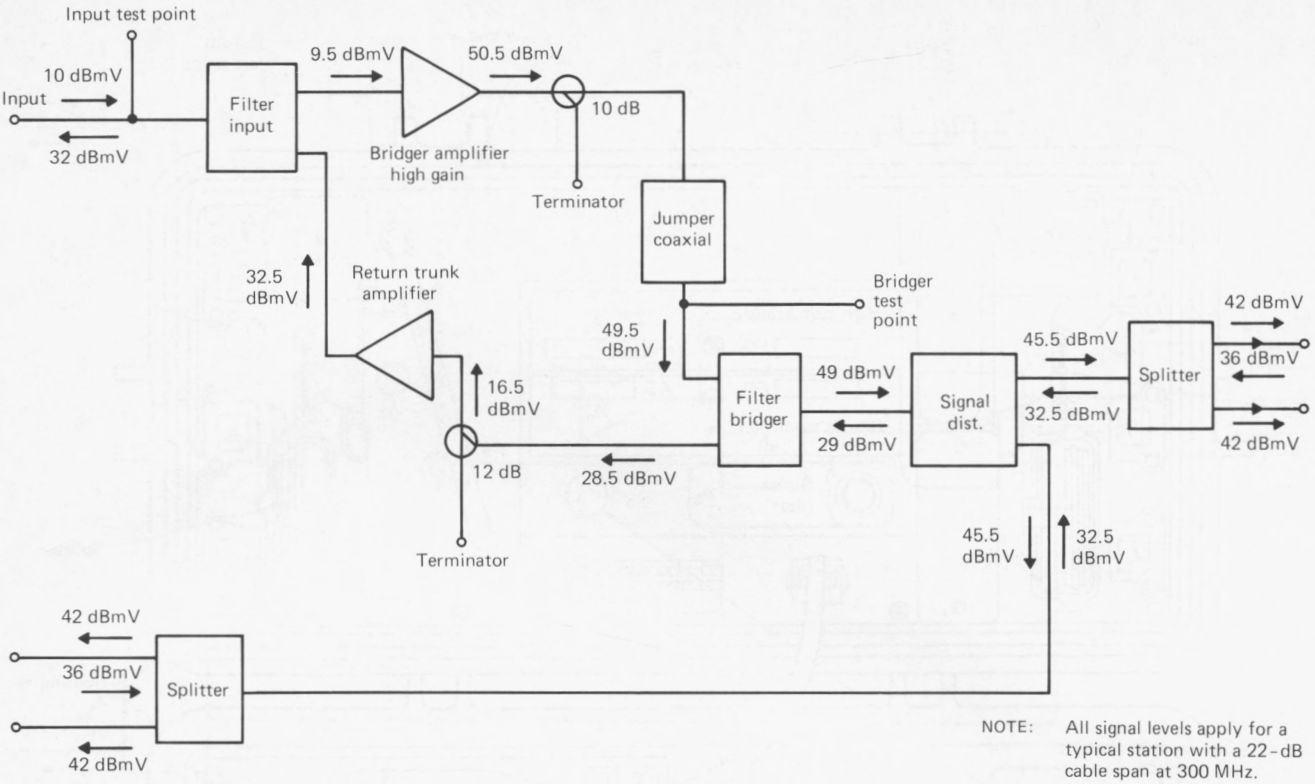


Fig. 7-7. Operational signal levels, bidirectional terminating bridger station (*Winegard Co.*).

THEORY OF OPERATION OF A DISTRIBUTION TRUNK AMPLIFIER STATION AND ITS MODULES

The distribution trunk amplifier–module system is outlined in this section.

Distribution Trunk Amplifier Station

Figure 7-10 is a block diagram of a bidirectional (two-way) trunk station. The trunk input signal is applied to a diplex filter A_3 whose output goes to the automatic trunk amplifier A_5. The trunk amplifier output is applied to directional coupler DC_1 and to an ASG amplifier A_4. The ASG amplifier detects the low and high pilot carriers, and the detector outputs maintain the gain and slope at a preset level. The output of directional coupler DC_1 goes to diplex filter A_9 and bridger amplifier module A_7. The bridger output is applied to yet another diplex filter A_8, whose output goes to a signal distribution card A_{12} and then to two splitter cards, A_2 or A_{10}.

Upstream signals (5 to 30 MHz) can be received through the trunk output line or feeder output lines. Diplex filters A_8 and A_9 connect these signals to directional coupler DC_2. The directional coupler is connected to the return trunk module input A_6, which supplies a return path for the signals to the trunk line through diplex filter A_3.

In Fig. 7-11 we see a more detailed block diagram showing the downstream RF signals applied to the input port routed through the trunk diplex filter and then applied to an equalizer at the input of the trunk amplifier module. The equalizer is used to compensate for most of the tilt caused by the cable. The signal is next applied to the first of the two amplifiers to achieve some gain and then to a slope control to achieve the final slope required at the output of the station. The signal is then fed through a gain control where adjustments are made to achieve system requirements. From the gain control, the signal is sent to a socket containing either an equalizer or a pad, depending on the design of the system. The signal then goes through the second amplifier, a directional coupler inside the trunk amplifier module, a second directional coupler DC_1, and the output diplex filter and back into the trunk cable. The directional coupler inside the trunk amplifier module is used to direct signals to the automatic gain and slope circuitry (insert 1). Directional coupler DC_1 is used to feed some of the forward trunk amplifier signals to the bridger amplifier, which provides further amplification for the signals entering the feeder cables. The output from the bridger amplifier then goes to a filter. From the bridger filter the signals go to the distribution cards and splitters, which provide for the selection of one to four distribution lines.

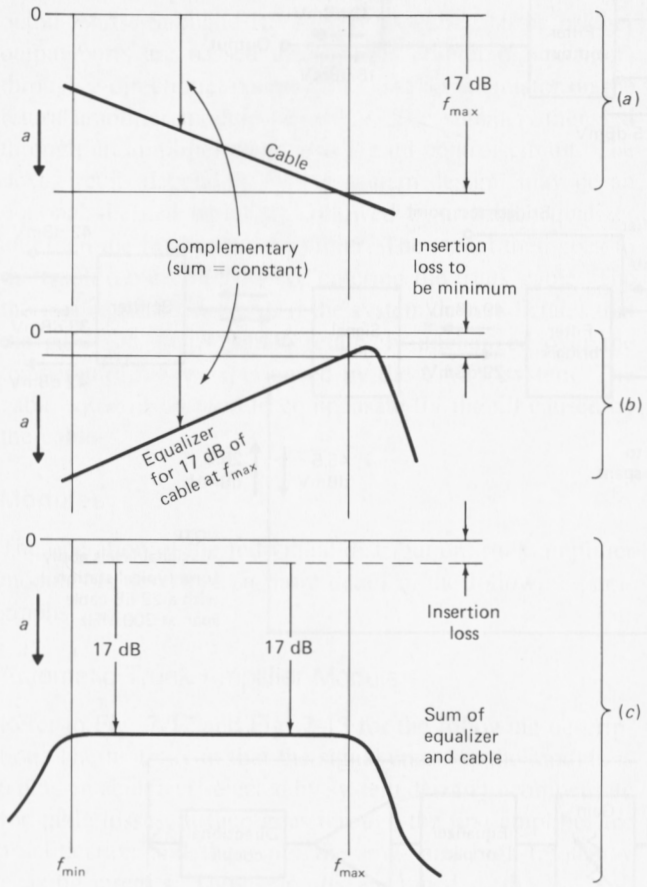


Fig. 7-8. Demonstration of equalizer characteristics: (*a*) cable only; (*b*) equalizer only; (*c*) cable plus equalizer (*Winegard Co.*).

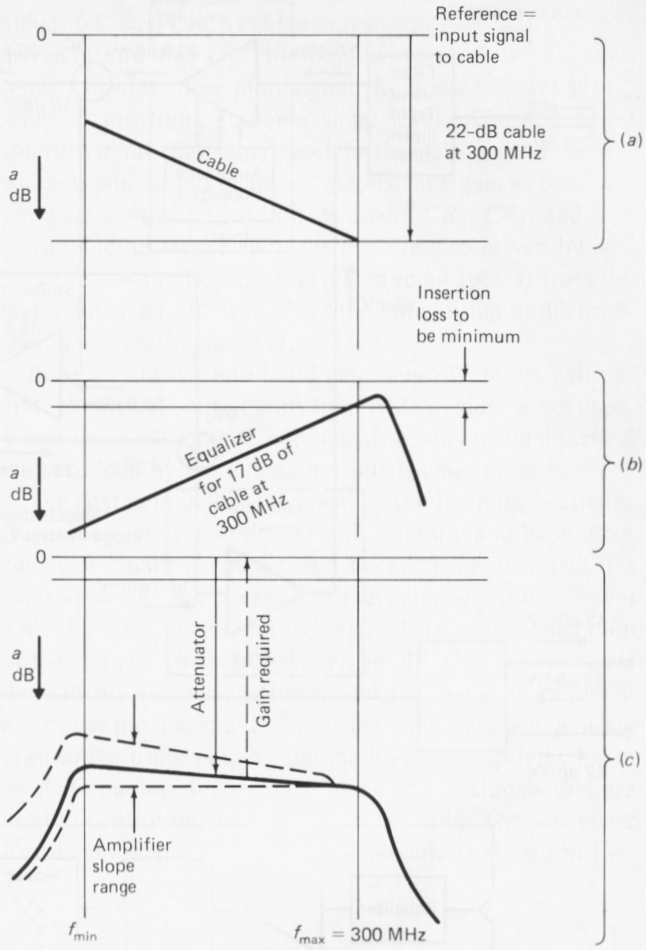


Fig. 7-9 Practical characteristics of equalizers: (*a*) cable only (tilt); (*b*) equalizer only (slope); (*c*) attenuation to signals = cable plus equalizer = negative of gain and slope in amplifier to drive next cable at reference level (*Winegard Co.*).

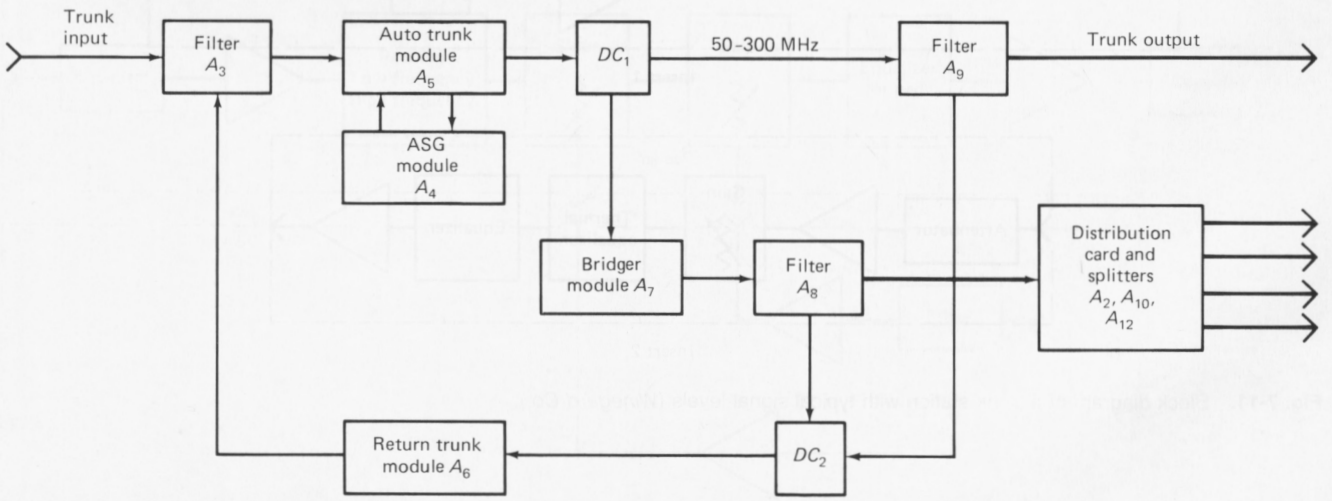


Fig. 7-10. Block diagram of bidirectional trunk station (heavy lines indicate bidirectional signal lines) (*Winegard Co.*).

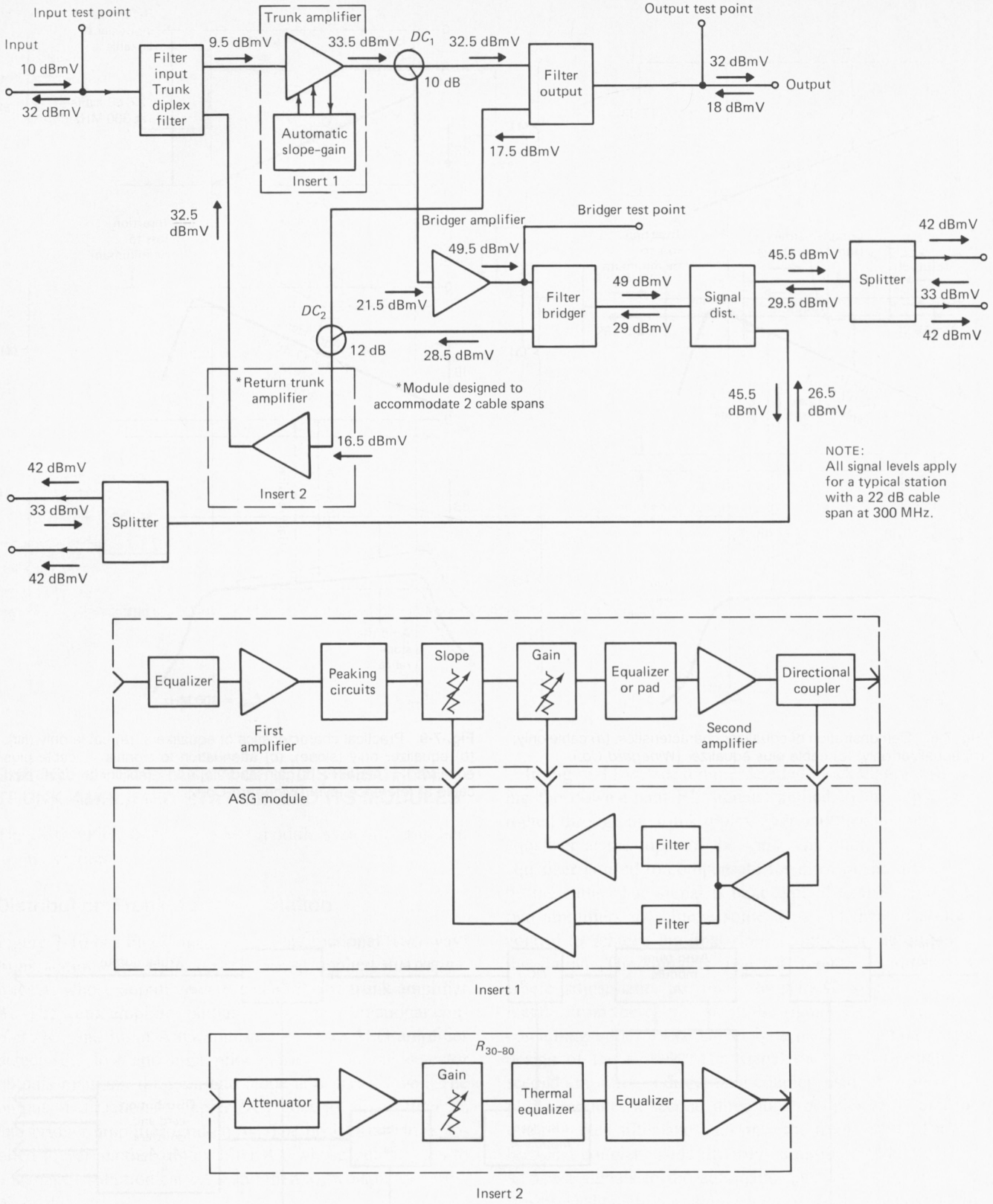


Fig. 7-11. Block diagram of a trunk station with typical signal levels (*Winegard Co.*).

Subband RF signals (5 to 30 MHz) may be applied to the station through either the trunk output port or the bridger output ports. Subband RF signals appearing at the bridger output ports are passed through the bridger diplex filter, through a directional coupler DC_2 into an attenuator on the return amplifier module (insert 2). The signal is then fed through an amplifier stage into a gain control circuit. The next circuit, depending on the system design, may be an optional thermal equalizer followed by a cable equalizer and then the final return amplifier. The signal then goes to the trunk diplex filter before entering the trunk cable. The thermal equalizer is added if the system design dictates that the gain and slope remain relatively unchanged over the temperature range experienced by the CATV system. The cable equalizer is used to compensate for the tilt caused by the cable.

Modules

The operation of the individual distribution trunk amplifier modules is described in more detail in the following paragraphs.

Automatic Trunk Amplifier Module

Refer to Fig. 7-12 and Fig. 7-13 for the following description. The first circuit that the signal enters in the module is a plug-in equalizer selected by system design to compensate for cable losses. It then goes through the first amplifier for amplification and then into the low- and high-frequency peaking circuits. These circuits are tuned to the low end (ca. 50 MHz) and to the high end (ca. 300 MHz) by C_7 and C_8, and give an overall flat response to all frequencies from 50 to 300 MHz. The next circuit is the slope control, which compensates for the change in slope due to temperature changes of the cable.The slope control circuit utilizes diodes CR_1 and CR_2 as variable resistance elements that are driven by amplifier U_3. This amplifier (U_3) receives an input (pin 3) from the low pilot signal. R_4 is used for the initial setup of the trunk station's slope level. After the slope control circuit, the signal goes to the gain control circuit, which is adjusted to maintain as constant a gain as possible. The gain control circuit utilizes diodes CR_3, CR_4, and CR_5 as variable resistance elements that are also driven by amplifier U_3. Amplifier U_3 receives an input (pin 5) from the high pilot signal. R_2 is used for the initial setup of the trunk station's overall gain level.

Both the slope control and gain control circuits will operate as manual control units if an ASG module is not used. When the ASG module is plugged in, this manual control is overridden by the automatic signals entering at E_2.

The next item in the signal path is another plug-in circuit. Depending on system design, this circuit could be another equalizer circuit if equalization is called for, or a pad if a short span of cable were used preceding the trunk station and additional attenuation is required for proper operation of the station. The signal is then amplified again as it goes through the second amplifier, and the last item before it leaves the module is a directional coupler. The low-loss leg goes to the trunk output, and the high-loss tap leg goes to an ASG module for the processing of the signals that are used to control the slope and gain controls. The schematic for the automatic trunk amplifier module is shown in Fig. 7-13.

Automatic Slope and Gain Control Module (ASG)

By referring to Figs. 7-12 and 7-14, we see that the ASG module plugs into the automatic trunk amplifier module for operation. Its RF input comes from the directional coupler at the output of the automatic trunk amplifier module, through

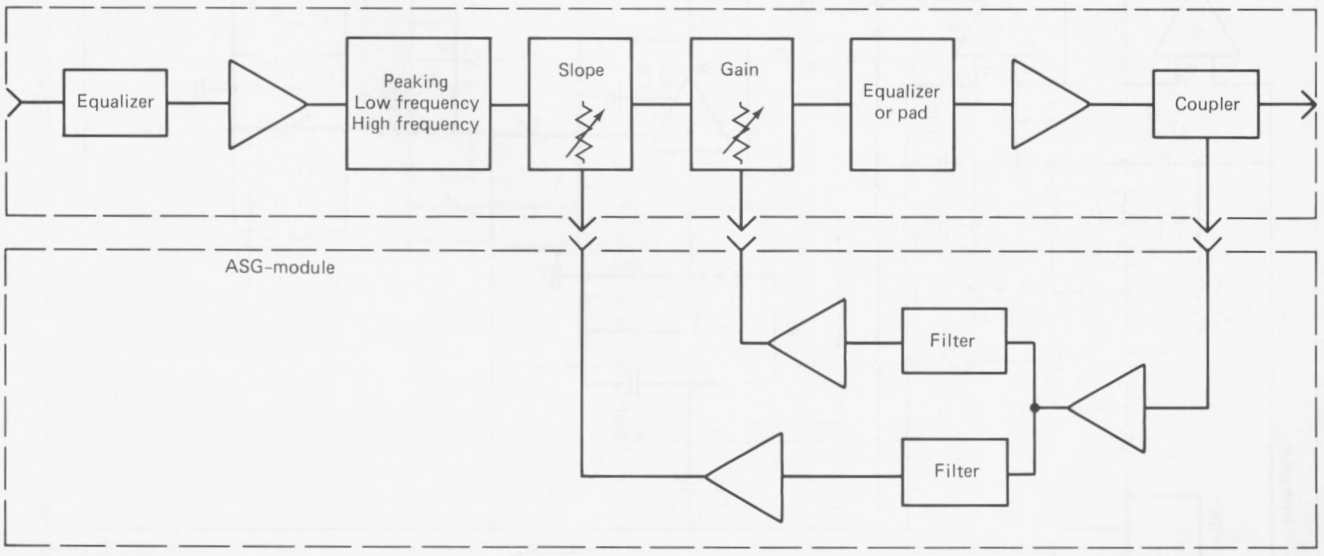


Fig. 7-12. Block diagram of automatic trunk amplifier and ASG modules (*Winegard Co.*).

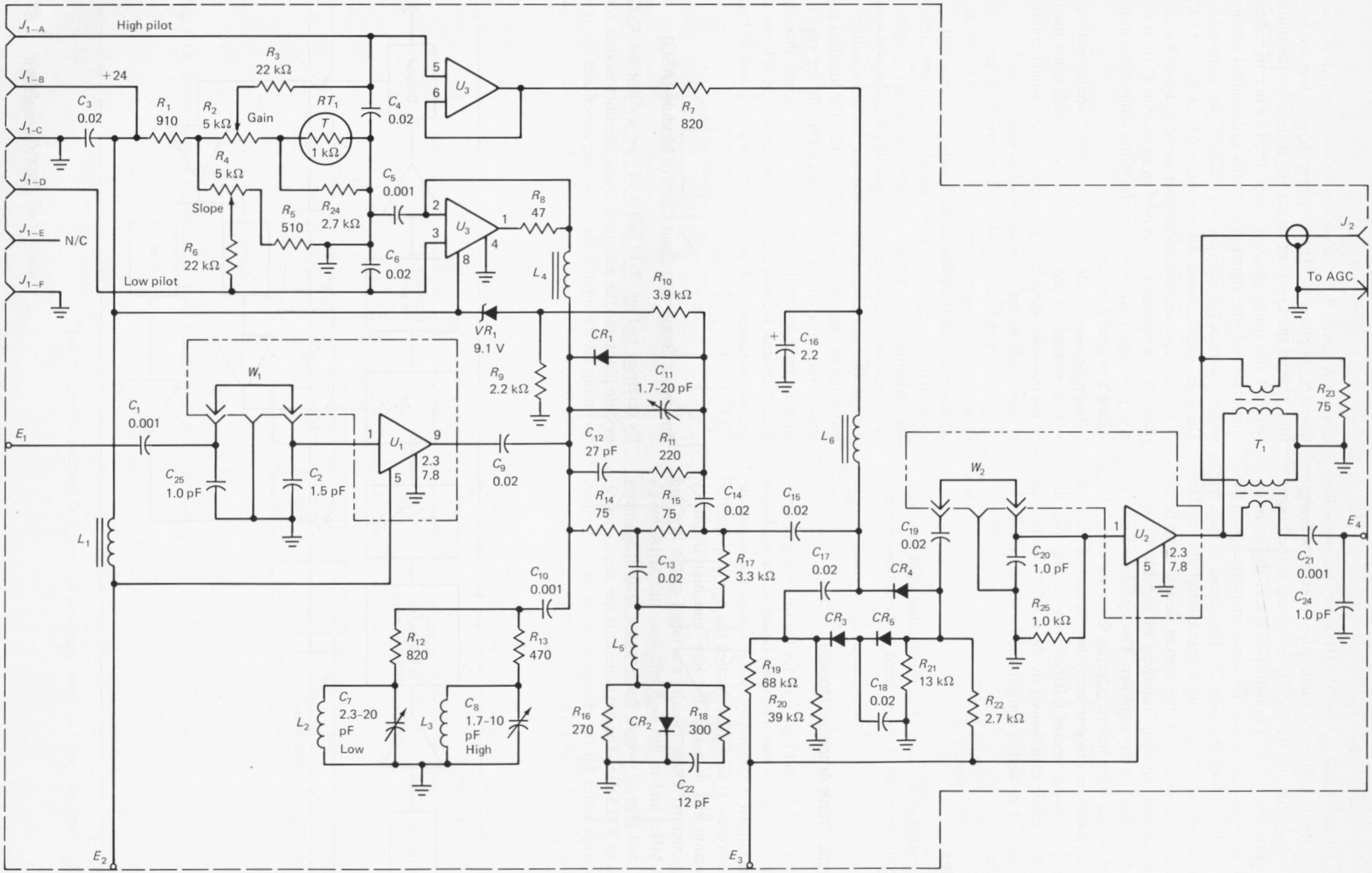


Fig. 7-13. Automatic trunk module schematic drawing (*Winegard Co.*).

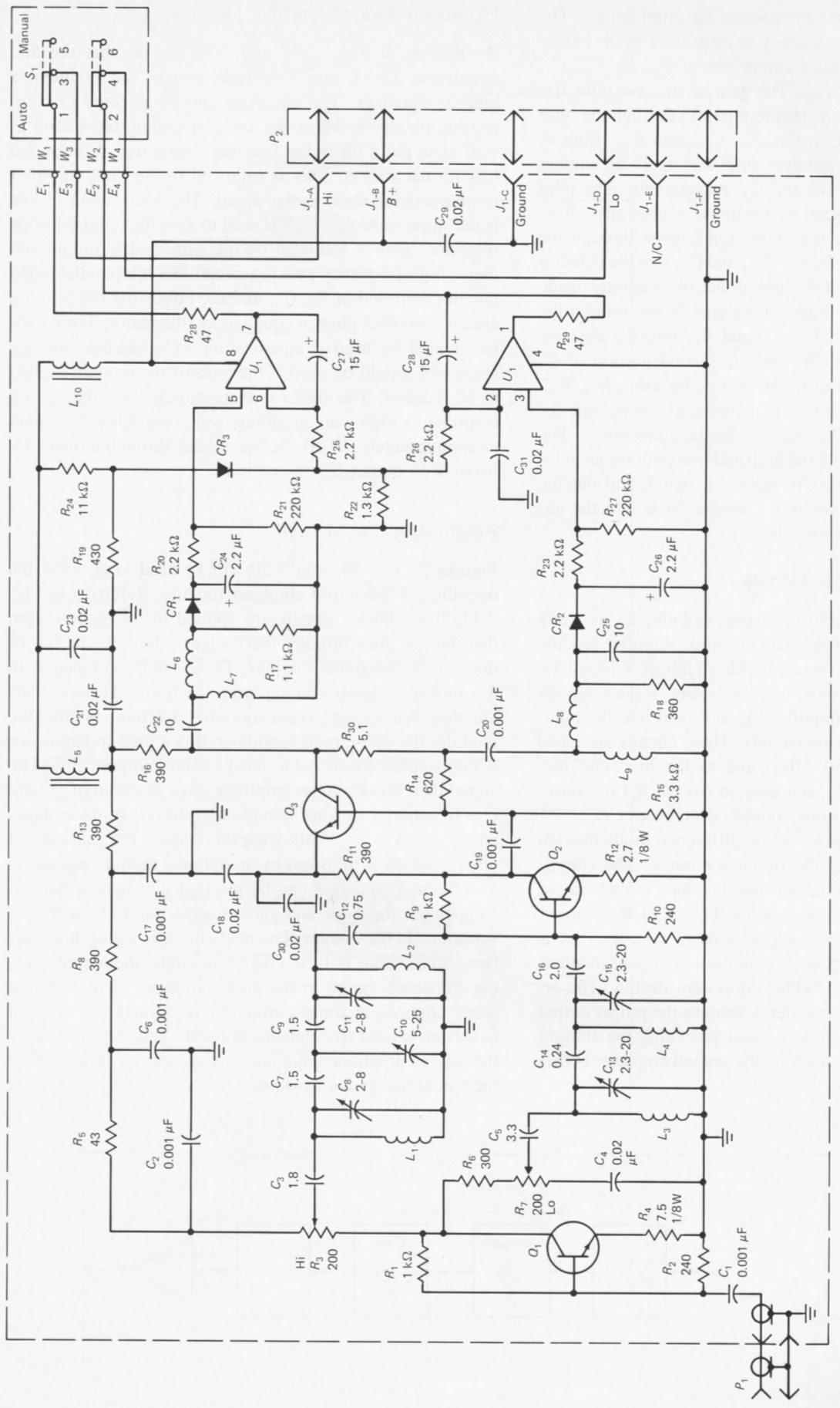


Fig. 7-14. Automatic slope and gain module schematic drawing (*Winegard Co.*).

an RF connector P_1 into a broad-band RF amplifier Q_1. The gain of the high pilot frequency is controlled by R_3 before it passes through the filter comprised of C_3, L_1, C_8, C_7, C_{10}, C_9, C_{11}, L_{12}, and C_{12}. The gain of the low pilot frequency is controlled by R_7 before it passes through the filter comprised of C_5, L_3, C_{13}, C_{14}, L_4, C_{15}, and C_{16}. Both of these pilot frequencies are then amplified again by another amplifier composed of Q_2 and Q_3, respectively. The pilot frequencies are split again by means of a high-pass, low-pass, diplex filter. The low pilot signal flows through the filter composed of C_{20}, L_9, L_8, R_{18}, and C_{25} into the detector circuit using the diode CR_2 and an active integrator made up of U_1 and C_{28}. The high pilot signal flows through the filter composed of C_{22}, L_7, L_6, and R_{17} into the detector circuit using the diode CR_1 and the second portion of U_1 and C_{27}. Both portions of U_1 are biased by using R_{24}, R_{19}, R_{22}, and CR_3. The diode CR_3 is included to compensate for changes to CR_1 and CR_2 over the temperature range. The dc signals that result from the high and low pilot frequencies are routed through the AUTO-MANUAL switch and out the socket through a printed-circuit jumper back into the automatic trunk amplifier module.

Manual Trunk Amplifier Module

To understand the operation of this module, let us study Figs. 7-15 and 7-16. If the manual trunk amplifier module is used, RF is applied to a plug-in equalizer selected by system design to compensate for cable losses. It goes through the first amplifier for amplification and then into the high- and low-frequency peaking circuits. These circuits are tuned to the low end (ca. 50 MHz) and to the high end (ca. 300 MHz) by C_5 and C_6 and give an overall flat response. The next circuit is the slope control, which uses CR_1, CR_2, Q_1, and R_4 to compensate for the difference in attenuation for the cable span over the frequency range. The combination of the correct equalizer and the slope circuit should give an overall flat response at the output of the station. The circuit after that is the gain control circuit. This is followed by two sockets which are used by a plug-in attenuator and equalizer depending on system design. The attenuator would be used in order to achieve the proper output when a short span of cable is used preceding the station. The signal is amplified again by the second amplifier before it leaves the module.

High-Gain Bridger Amplifier Module

By looking at Figs. 7-17 and 7-18 we see that the first circuit that the RF signal meets as it enters the module is a plug-in equalizer. The equalizer can be selected to compensate for the losses in the cable preceding the station as well as to put a tilt in the frequency response of the signal leaving the station. This is followed by the first amplifier to give amplification to the signal. The next circuit in line is the slope control, which is used to give the required slope response. This is followed by the gain control circuit and then a high-frequency peaking circuit that is a parallel tuned circuit composed of R_8, C_9, and L_2. Following the peaking circuit is another plug-in equalizer or attenuator. The equalizer would be used if equalization were needed, and the attenuator would be used if the gain of the module needed to be reduced. The signal is then amplified by the second amplifier, a high gain amplifier, which amplifies the signal to approximately 33 dB, before it goes through a matching network to output E_3.

Return Amplifier Module

Figures 7-11, 7-19, and 7-20 will be used to describe the operation of the return amplifier module. Referring to Fig. 7-11, the subband signals are applied to the station from distribution lines through the bridger filter and the tap of the return directional coupler, DC-2, and combined with the subband signals coming from the trunk. These signals are then fed to the return amplifier module. Within the module, the first circuit encountered is a plug-in attenuator which would be selected to meet system requirements. The signal then flows into an amplifier stage made up of Q_1 and Q_2. To achieve the least second-order distortion, these stages are balanced by R_{11}. Following this stage is the gain control circuit, which is followed by an optional thermal equalizer. The thermal equalizer can be inserted if it is necessary to compensate for slope and gain changes due to temperature variations in the system. The next circuit is a plug-in equalizer. Since there is little change in cable attenuation over the frequency range in the subband, there is no variable slope control. If some correction is needed, the plug-in equalizer is used to compensate for it. This is followed by the second amplifier stage and then a low-pass filter before the signal leaves the module.

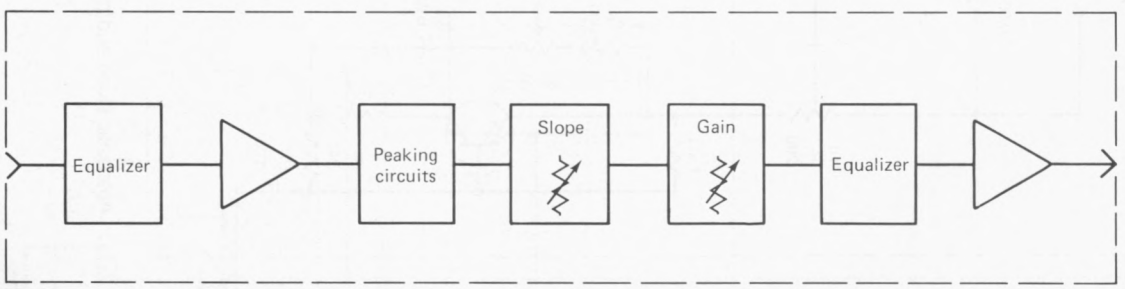


Fig. 7-15. Block diagram of a manual trunk amplifier module (*Winegard Co.*).

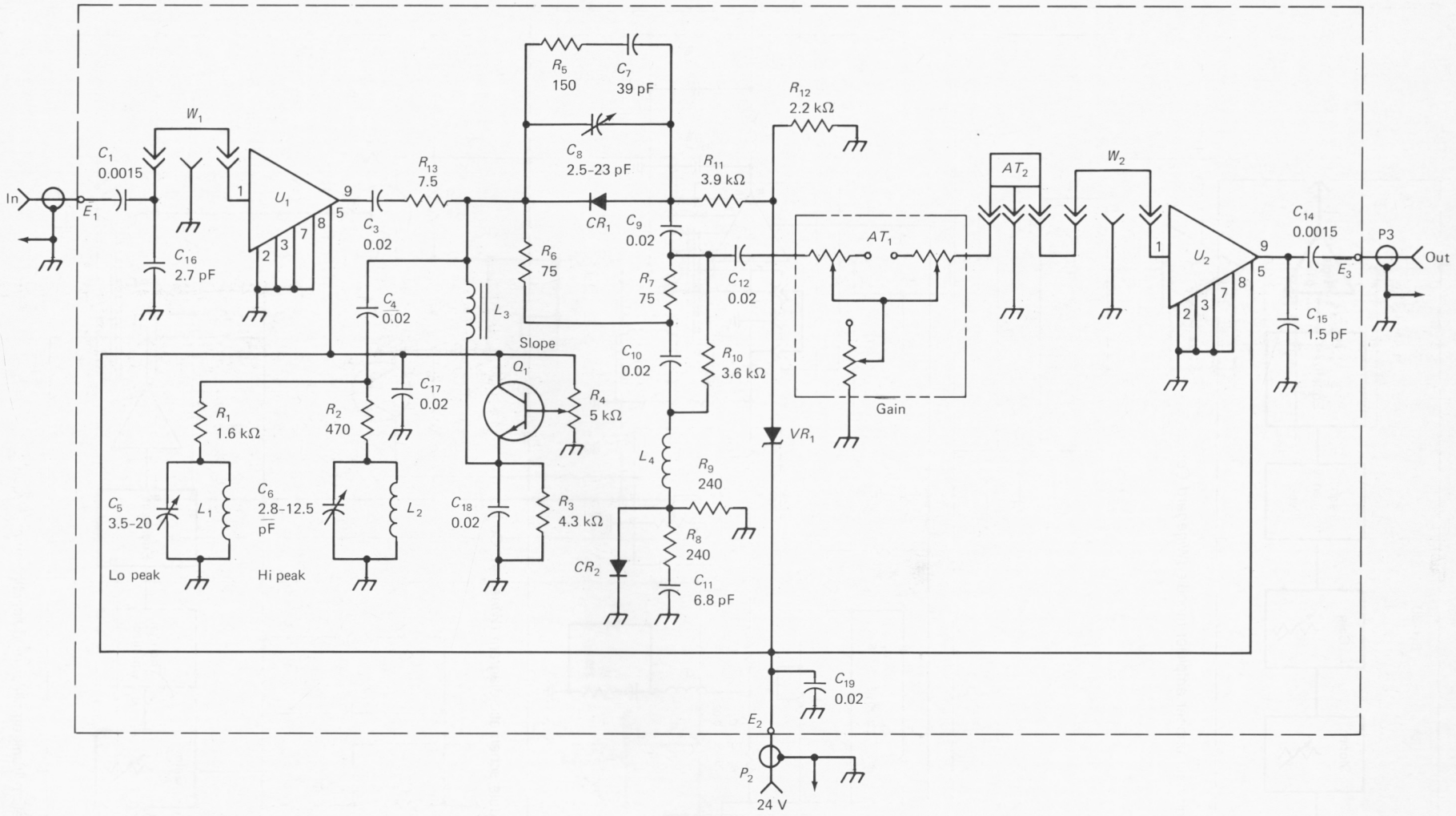


Fig. 7-16. Manual trunk amplifier module schematic drawing (*Winegard Co.*).

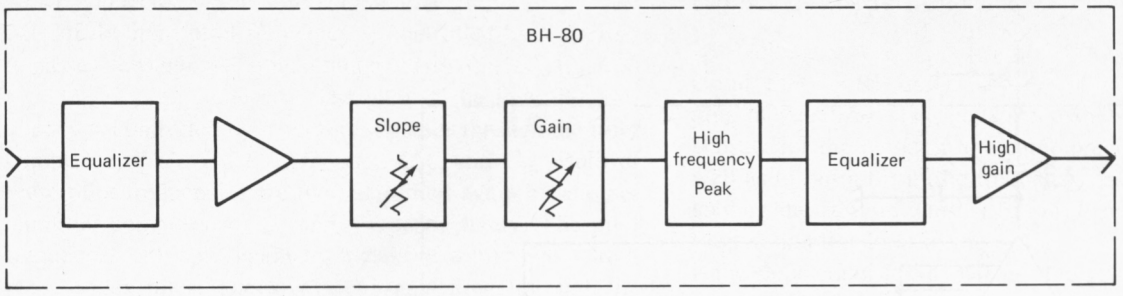


Fig. 7-17. Block diagram of a high-gain bridger amplifier module (*Winegard Co.*).

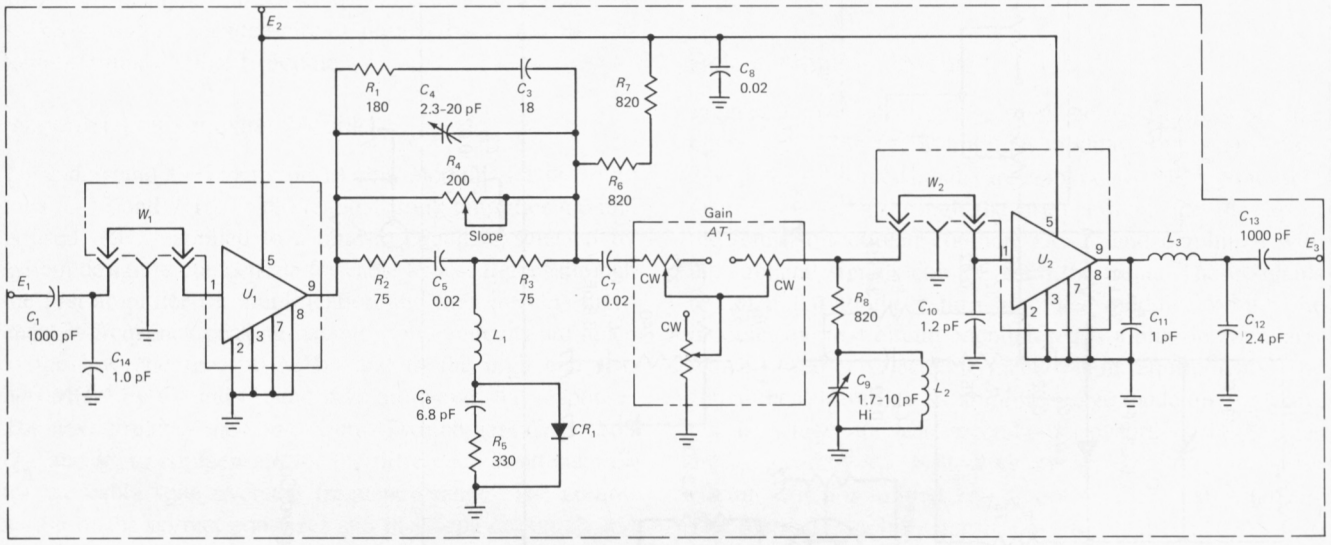


Fig. 7-18. High-gain bridger module schematic diagram (*Winegard Co.*).

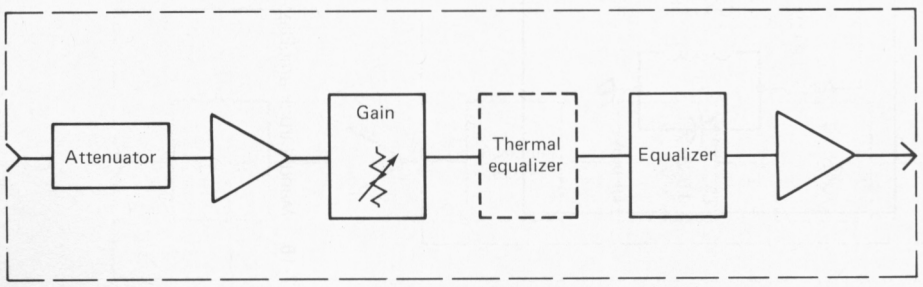


Fig. 7-19. Block diagram of a return trunk amplifier module with thermal equalizer (*Winegard Co.*).

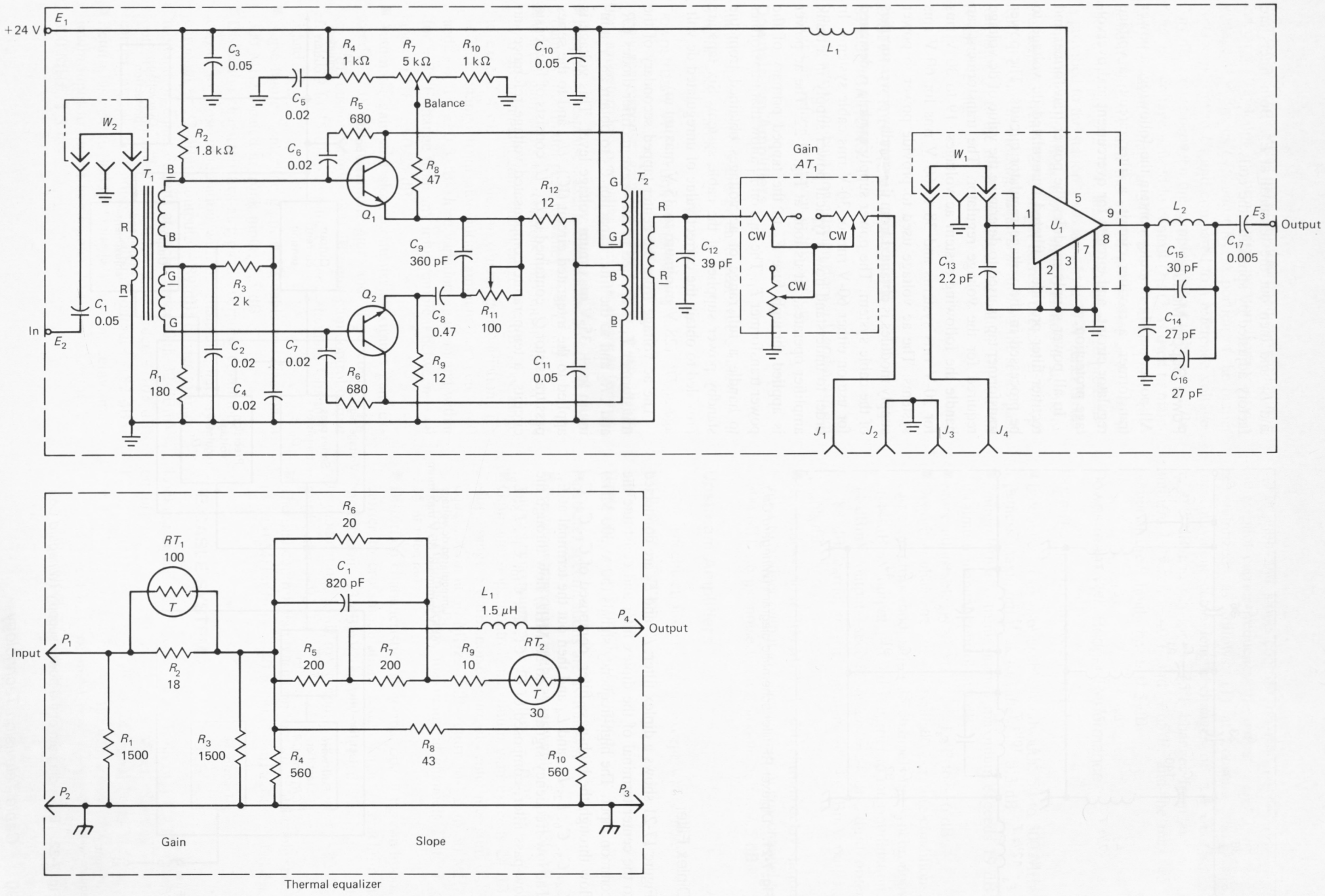


Fig. 7-20. Return trunk amplifier module schematic diagram (*Winegard Co.*).

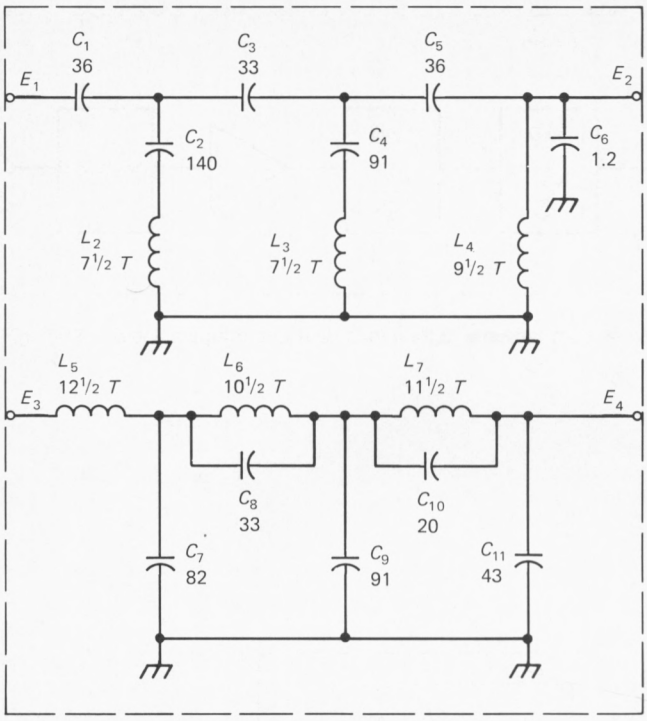


Fig. 7-21. Diplexer RF filter schematic diagram (*Winegard Co.*).

Diplex Filter

Figure 17-21 shows a diplex filter; E_1 and E_2 are connected to the center terminal of the diplex filter and constitute the common input. The high-frequency signals (50 to 300 MHz) flow through the high-pass filter, composed of C_1, C_2, C_3, C_4, C_5, C_6, L_2, L_3, and L_4 and then out the terminal at E_2. The low-frequency signals (5 to 30 MHz) flow through the low-pass filter, composed of C_7, C_8, C_9, C_{10}, C_{11}, L_5, L_6, and L_7 and then out the terminal at E_4. Both filters are factory adjusted by spreading the coils.

Power Supply Module

All power supply modules contain the following: a power transformer, a rectifier circuit, a filter circuit, a voltage regulator circuit, and circuits for overcurrent and overvoltage protection.

In all power supply modules the power transformer and rectifier-filter provide a filtered unregulated dc voltage to be processed in the voltage regulator circuits. The power transformer tap is used to determine the value of dc voltage required for the voltage regulator. The transformers can handle the following system ac voltages: 19 to 30 V rms for 30-V rms systems and 38 to 60 V rms for 60-V rms systems. The ac voltage used to provide power to power supply modules is obtained from the standby power supplies of the cable system. The power supply module is designed for use on either 60-V rms or 30-V rms cable systems. In order to understand how a typical power supply in a trunk amplifier operates, let us look at Fig. 7-22. The ac power is applied through fuse F_1 to the tapped primary of the power transformer T_1. The taps on T_1 allow that transformer to handle a full range of ac voltages obtained from the standby power supplies of the cable system. Six taps are provided to obtain the correct value of unregulated dc voltage at TP_1 (28 V minimum to 35 V maximum).

The ac voltage from the center-tapped secondary of the transformer T_1 is applied to full-wave rectifier diodes CR_1 and CR_2 and to the filter capacitor C_2 to obtain 28 V minimum to + 35-V maximum voltage level. This voltage is applied to the integrated circuit (IC), U_1, and to the series pass transistor Q_1 contained in U_1. U_1 consists of four basic circuits, a temperature-compensated voltage reference, an

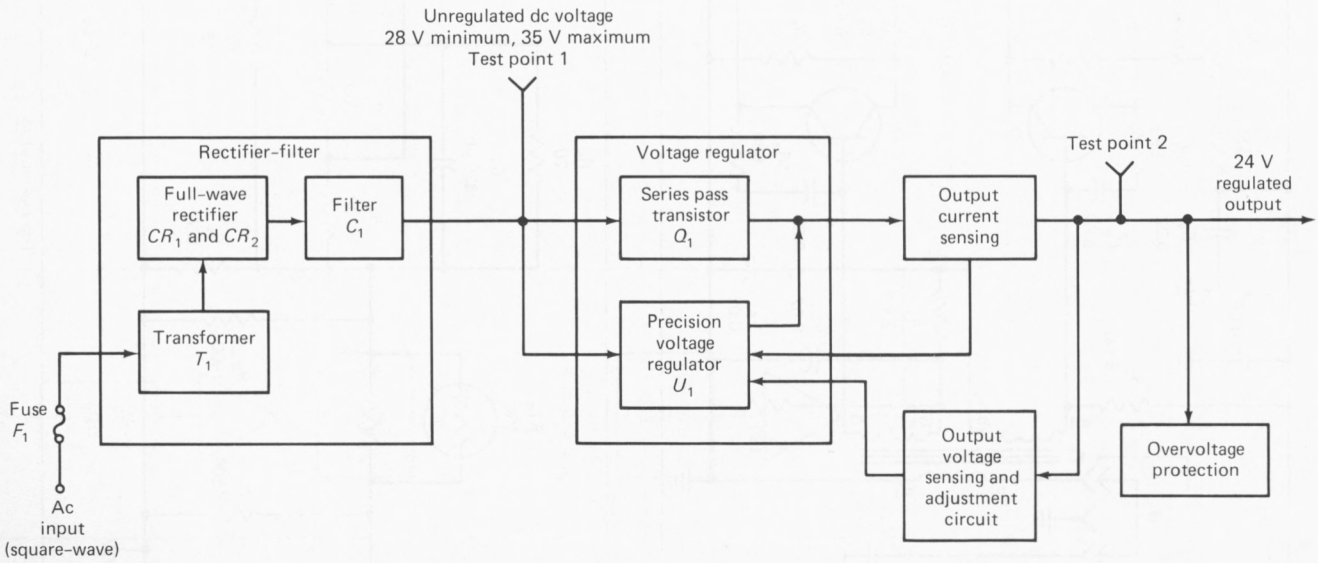


Fig. 7-22. Block diagram of the power suppply (*Winegard Co.*).

error amplifier, a series pass transistor, and current limiting circuitry. Capacitor C_2 provides protection from transient voltages for diodes CR_1 and CR_2. A portion of the output voltage is sent to U_1 and compared to a reference voltage. Any difference between the sampled output voltage and the reference voltage is used to control Q_1; Q_1 is used to maintain the output voltage at 24 ± 0.1 V. The output voltage is adjustable through the use of potentiometer R_8. R_8 is shown in Figs. 7-2, 7-4, and 7-6. Overvoltage protection is provided to the station's modules by a 27-V zener diode.

The current-limiting circuitry in U_1 monitors a sample of the output current. If the output current exceeds 2 A (typical), the current-limiting circuit will turn off the series pass transistor Q_1 to the maximum specified value. This circuit is self-resetting.

DISTRIBUTION TRUNK AMPLIFIER SPECIFICATIONS

Specifications for both downstream (forward) and upstream (return) amplifiers are given in this section.

Downstream Amplifiers

Station specifications are given except where noted as a module specification.

Downstream VHF Trunk Performance

Frequency response, gain and slope control, noise, distortion, and return loss parameter specifications are as follows:

- Frequency responses: usable bandwidth, 50 to 300 MHz; flatness, maximum peak to valley, ±0.15 dB
- Manual gain and slope controls: maximum gain exceeds 27.0 dB; minimum gain control range, 8.0 dB; slope range to exceed 4 dB of cable; maximum gain variation, for +75°F change from any initial ambient between −40 and +60°F, ± 0.5 dB; slope variation, random and within for +75°F change from any initial ambient between −40 and +65°F, ± 0.25 dB
- Automatic gain and slope controls: maximum gain exceeds 27.0 dB; minimum gain and slope control for ± 3-dB output changes, 8.0 dB; pilot gain control output levels 29 to 35 dBmV; pilot carriers, standard Channels 5 and 12
- Noise figure: centerline gain, 0-dB cable equalization at 300 MHz located at trunk input, 7.5 dB
- Distortion characteristics at typical operating conditions: carrier to cross modulation with 35 channels, flat, synchronous at 32-dBmV output, −89 dB; carrier to intermodulation equal outputs at each carrier with 32-dBmV output—second order − 87 dB, third order −103 dB; carrier to triple beat noise, 32-dBmV output, −87 dB
- Return loss: 50 to 300 MHz, 16 dB; chroma delay, maximum input to output at Channel 2 or at any channel to 300 MHz, 4.5 ns

For gain and slope controls on the automatic unit, at either pilot carrier frequency the output amplitude should be stabilized, as follows: (1) at constant temperature for equivalent cable length changes of ±4 dB, within ± 0.3 dB and (2) for + 75°F change, from any initial ambient between −40°F and +65°F, and the maximum output change should be ± 0.5 dB.

Downstream VHF Bridger Performance

Parameter specifications are as follows:

- Frequency response: usable bandwidth, 50 to 300 MHz; flatness maximum peak to valley, ± 0.3 dB
- Gain relative to trunk output: maximum exceeds 19 dB; minimum manual control, 10 dB
- Slope adjustable at 50 MHz, + 1 dB to −6 dB
- Distortion characteristics at typical operating conditions: carrier to cross modulation 35 channels flat synchronous at 44-dBmV output, −69 dB; carrier to intermodulation, 44-dBmV output—second order −74 dB, third order −83 dB; carrier to triple-beat noise, 44-dBmV output, −65 dB
- Return loss: 50 to 300 MHz, 16 dB; chroma delay station input to bridger output at Channel 2 or at any channel to 300 MHz, 6 ns; noise figure (module only), 7.5 dB

Upstream Amplifiers

Station specifications are given except where noted as a module specification.

Upstream VHF Trunk Performance

Parameter specifications are as follows:

- Frequency response: usable bandwidth, 5.0 to 30 MHz; flatness, maximum peak to valley, ± 0.25 dB
- Gain and slope control: maximum gain exceeds 24 dB, slope range 5.0 dB; noise figure at centerline gain, 0-dB equalization at 30 MHz, 7 dB; return loss 5 to 30 MHz, 18 dB; chroma delay, maximum at channels T_7 to T_{10}, 15 ns
- Distortion characteristics at normal operating conditions: carrier to crossmodulation, four channels, synchronous modulation, 33-dBmV output, −114 dB; carrier to intermodulation, 33-dBmV output—second order −92 dB, third order −92 dB
- Thermal control: gain variation for two 22-dB cable spans (at 300 MHz) from −40 to 60°C, limited to ± 1.0 dB

THE CABLE SYSTEM AS A WHOLE

Looking at Fig. 7-23, we see a portion of a CATV distribution system from head-end to TV set. Starting at the head-end (1) there is 32 dBmV of signal being sent to a trunk amplifier (3). Because of the attenuation of the trunk cable (2), 20 dBmV of the signal strength is lost, thus limiting the input to the trunk amplifier to 12 dBmV

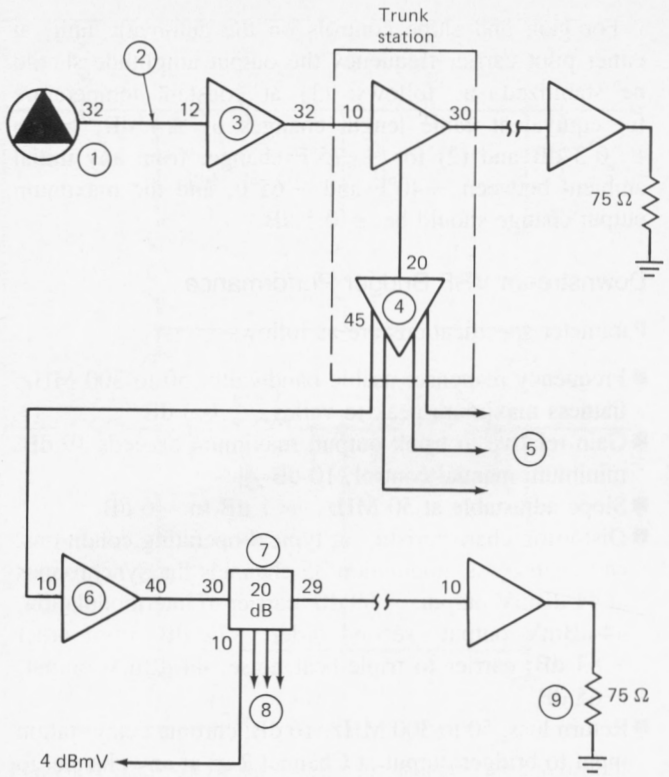


Fig. 7-23. CATV distribution system.

(32 − 20). Since the trunk amplifier has a 20-dB gain, the level of the signal is again 32 dBmV. The signal continues to a trunk station where the signal is again amplified by a trunk amplifier. In this trunk station, a portion, 20 dBmV, of this signal is sent to the bridger amplifier module (4), where it is reamplified and split into four separate feeder lines (5). The signal leaves the bridger amplifier with a value of 45 dBmV and is sent to a line-extender amplifier (6). The line-extender amplifier then boosts the 10-dBmV signal to 40 dBmV and sends it to the next line-extender amplifier. In the feeder cable, located between the bridger amplifier and the terminator (9), are the tap-off devices (7) that supply the subscribers with signal. In Fig. 7-23 we can see that a tap is located between the two line-extender amplifiers. Coming from this tap are four drop cables (8).

Notice that the input to the tap is at a level of 30 dBmV and the level of the signal at the tap output ports are 10 dBmV. This is because 20 dBmV of signal (30 − 10) has been attenuated by the tap in order to drop the signal strength to a level that would not supply the subscriber's TV set with too much signal. Also, notice that only about 1 dBmV of signal was lost with insertion of the tap-off device (30 dBmV in, 29 dBmV out). We also see that 6 dBmV of signal is lost in the drop cable, resulting in 4 dBmV of signal arriving at the subscriber's TV.

SUMMARY

1. Amplifiers used in cable systems must possess high gain, extended bandwidth, exceptional flatness, and low distortion and noise and have high stability under varying temperature extremes.
2. The four types of amplifier stations are the trunk, intermediate bridger, terminating bridger, and line-extender amplifier stations.
3. The component parts of a typical trunk station are (*a*) test points and jacks; (*b*) filters; (*c*) jumpers; (*d*) fuses and circuit breakers; (*e*) splitters; (*f*) distribution cards; (*g*) amplifier modules; (*h*) automatic slope and gain modules; (*i*) power supply; (*j*) input, output, and base plates; (*k*) surge protectors; (*l*) equalizers; and (*m*) attenuators.

REVIEW QUESTIONS

1. Name the four types of amplifier stations.
2. What is the purpose of the splitter in a trunk station?
3. How much voltage does the power supply provide to the amplifier circuits?
4. Why are equalizers used in amplifier stations?
5. What is the frequency range of the return signal?
6. Explain the function of the ASG module.
7. Name four principal parts of a power supply used in an amplifier station.
8. Where is a terminating bridger station located in a cable distribution system?

8 CHAPTER

CATV SYSTEMS ANALYSIS

INTRODUCTION

In this chapter you will learn about:

1. Methods for analysis of a portion of a distribution system and determination of the values of amplifiers, multitaps, signal splitters, and directional couplers
2. The various maps that are used in the cable industry
3. The different symbols used on CATV maps
4. Manufacturers' literature, tables, and charts

At this point we should be familiar with the entire distribution system as well as the major active and passive devices used.

Let us now consider systems analysis and design, not from the viewpoint of the systems engineer, but the service technician. A knowledge of systems analysis is invaluable whenever a portion of the distribution system malfunctions or additions are made to an existing section of cable plant.

To analyze a portion of the distribution system, service personnel use system maps, periodic signal measurements, and knowledge of simple system design.

SYSTEMS ANALYSIS

In Fig. 8-1 you will find approximate values of coaxial cable attenuation and tap insertion losses. Tap insertion loss is the amount of signal lost as it passes through the multitap.

The values given in Fig. 8-1 are general rule-of-thumb values only and are not to be taken literally. The actual value of a particular size of coaxial cable depends on its manufacturer.

Also included are the formulas needed to solve for unknown values of tap size, amplifier size, total attenuation, directional coupler size, and TV signal level.

Following are some examples of simple circuits that we will analyze together. Pay very close attention to how these examples are worked. Although they are only examples, they will help you understand the procedures needed to obtain approximate values when working with actual situations in the field.

Because coaxial cable attenuation values change with both frequency and temperature, all the examples given will be based on a CATV system that is operating at 50 to 300 MHz with a cable temperature of 68°F.

Formulas

1. Tap size = amplifier value minus total losses.
2. Amplifier size = tap value plus total losses.
3. Attenuation = amplifier value minus total losses.
4. Directional coupler = amplifier value minus total losses.
5. Signal at set = amplifier value minus total losses.

Cable Attenuation Losses

1 in.	1.000	= 0.62 dB/100 ft
⅞ in.	0.875	= 0.81 dB/100 ft
¾ in.	0.750	= 0.90 dB/100 ft
½ in.	0.500	= 1.31 dB/100 ft
412	0.412	= 1.63 dB/100 ft
RG-6/u	—	= 4.00 dB/100 ft
RG-59/u	—	= 4.75 dB/100 ft

Tap Insertion Loss

Tap No.	*Two-way*	*Four-way*	*Eight-way*
45–27	0.40	0.40	0.60
26–23	0.40	0.40	0.80
22–20	0.50	0.80	0.90
19–15	0.80	0.90	1.80
14–12	1.00	2.00	3.30
11–7	2.00	3.20	Term.

Fig. 8-1. Cable and multitap losses and problem-solving formulas.

Example 1

Looking at Fig. 8-2, we see that in the portion of the system shown, there are an amplifier, four (4) four-way taps, two (2) two-way taps, and a terminator.

Interconnecting all of these is 0.412 (0.412-in.) feeder cable. We can also see that type RG-59/U subscriber drop cable is to be used to bring the signal from the tap-off devices into the subscriber's home and that approximately 5 dBmV of signal must be present at the subscriber's TV set. Our problem, therefore, is to determine what values of tap-off devices should be inserted into the feeder cable to maintain the 5 dBmV of signal at the TV set for each subscriber on this section (leg) of the system. To keep track

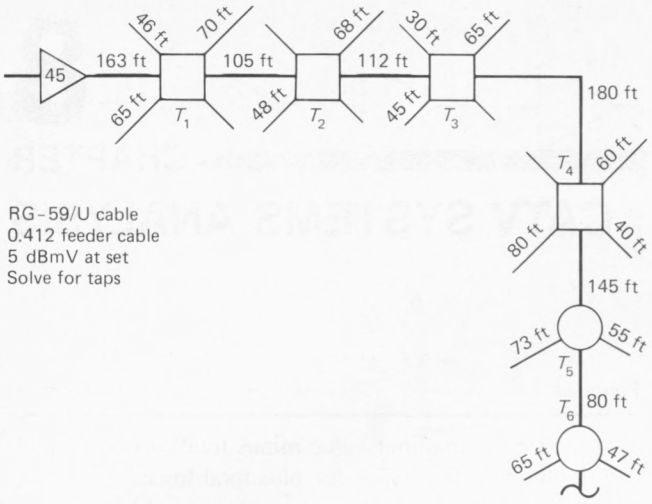


Fig. 8-2. System problem 1.

of our calculations, we have included a worksheet (Fig. 8-3) with each problem that we will solve. We strongly recommend that you use the worksheet when solving these types of problems because they will allow you to keep your calculations in an orderly form.

Solution

From Fig. 8-1 we see that the formula for determination of the correct size (attenuation value) of multitap to use is

$$\text{Tap size} = \text{amplifier} - \text{total losses}$$

In this problem the output of the line-extender amplifier is given as 45 dBmV. If we find the total loss and subtract it from 45 dBmV, we will find the value of the first tap T_1.

The total losses are made up of feeder-cable losses, drop-cable losses, tap insertion losses, the level of signal needed at the TV set, and any other losses offered by the system.

To determine what the value of tap T_1 should be in order to provide 10 dBmV at its ports, let us study Example 1. We see that 163 ft of feeder cable is used to connect it to the amplifier and that two of its four ports are connected to subscribers through drop cables 65 and 70 ft each. Using the worksheet, we see that the first calculation we must make is the loss of the feeder cable. From Fig. 8-1 we find that the loss of 0.412 cable is 1.63 dB/100 ft. If we multiply the length of the feeder cable by the loss per 100 ft, we will find its total loss. Remember that the loss is given per 100 ft; therefore, it will be necessary to divide the total length of the cable by 100 to obtain the correct value for multiplying. The loss of 163 ft of 0.412 cable is thus

$$\begin{array}{r} 1.63 \text{ (loss of 0.412 cable/100 ft)} \\ \times 1.63 \text{ (length of cable/100)} \\ \hline 2.6569 \text{ dB} \end{array}$$

We now place this value in column 1 of the worksheet (Fig. 8-4). Next find the loss due to the drop cable. Since the greatest loss will be in the longest subscriber cable, by using this value we can be certain of delivering the minimum (5 dBmV in this case) signal to the subscriber's TV set. The longest subscriber drop is the 70-ft drop, and its loss per 100 ft is 4.75 dB. If we multiply 4.75 times the length of the drop (remember to divide by 100), its loss can be found. Therefore

$$\begin{array}{r} 4.75 \\ \times 0.7 \\ \hline 3.325 \text{ dB} \end{array}$$

We also place this value in column 1 of the worksheet.

Now we must calculate the tap insertion loss. Pay close attention, because this can be tricky. We can see in Fig. 8-1 that four-way taps can cause from 0.4 to 3.3 dB of loss depending on the value of the tap. The primary issue then is how to determine the correct insertion loss if the tap value is unknown. For this, we must study the problem stated in Example 1 and make an educated guess. We can see that tap 1 must be smaller than the signal entering it. With 45 dBmV of signal exiting the amplifier, the size of the tap must be approximately 34 dB. We arrive at this value by subtracting the known losses at this point (2.65 + 3.32 + 5.0) from the value of the amplifier. Thus we must find the insertion loss for a tap of this size. We see that 0.4 dB will be the loss until a 22 or similar tap is used; therefore, we put 0.40 into column 1 for the tap insertion loss. If you later find that you guessed incorrectly for the value of insertion, the value on the worksheet can be simply changed to obtain the correct tap size. Since there are no splitters or directional couplers in this portion of the cable, the only other loss to be included on the worksheet is the amount of signal required at the subscriber's TV set.

Figure 8-2 tells us that this value is 5 dBmV. Adding all of these losses together, we obtain a total of 11.37 dB. Substituting this value into the equation, we get

$$45 - 11.37 = 33.63 \text{ dB}$$

When determining tap sizes, we always drop the fractional part of the answer, making the value of tap 1 equal to 33 dB.

Now work out the rest of the problem in pencil and compare your answers with Fig. 8-5. Remember the following rules when working problems of this type:

1. Feeder-cable losses and tap insertion losses are additive on each section (leg) of the problem.
2. Drop-cable losses are applicable only to the individual tap.
3. Use only the longest drop cable loss for each tap calculation.
4. Round off lower for taps and higher for amplifiers.

Example 2

In Example 2 we are asked to find the value of taps T_1 to T_6 as well as the amplifier. In this example (Fig. 8-6) we have introduced a device known as a *splitter*. As stated earlier, a splitter is a device that effectively splits the signal

System Problem Worksheet

Student name _____ Date _____

Amplifier output _____

Tap No.	Feeder Cable	Drop Cable	Tap Insertion	TV Signal	Splitter Loss	Directional Coupler	DC Insertion	Tap Value	Total Losses	Tap Size
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										

Fig. 8-3. System problem worksheet.

System Problem Worksheet

Student name _____ Date _____

Amplifier output 45 dB

Tap No.	Feeder Cable	Drop Cable	Tap Insertion	TV Signal	Splitter Loss	Directional Coupler	DC Insertion	Tap Value	Total Losses	Tap Size
1	2.65	3.32	0.40	5.00	–	–	–	–	11.37	33
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										

Fig. 8-4. Partial solution to problem 1.

System Problem Worksheet

Student name _____ Date _____

Amplifier output 45 dB

Tap No.	Feeder Cable	Drop Cable	Tap Insertion	TV Signal	Splitter Loss	Directional Coupler	DC Insertion	Tap Value	Total Losses	Tap Size
1	2.65	3.32	.40	5.00	–	–	–	–	11.37	33
2	4.36	3.23	.80	5.00	–	–	–	–	13.39	31
3	6.19	3.08	1.20	5.00	–	–	–	–	15.47	29
4	9.12	3.80	1.60	5.00	–	–	–	–	19.52	25
5	11.49	3.46	2.00	5.00	–	–	–	–	21.95	23
6	12.79	3.08	2.50	5.00	–	–	–	–	23.37	21
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										

Fig. 8-5. Solution to Problem 1.

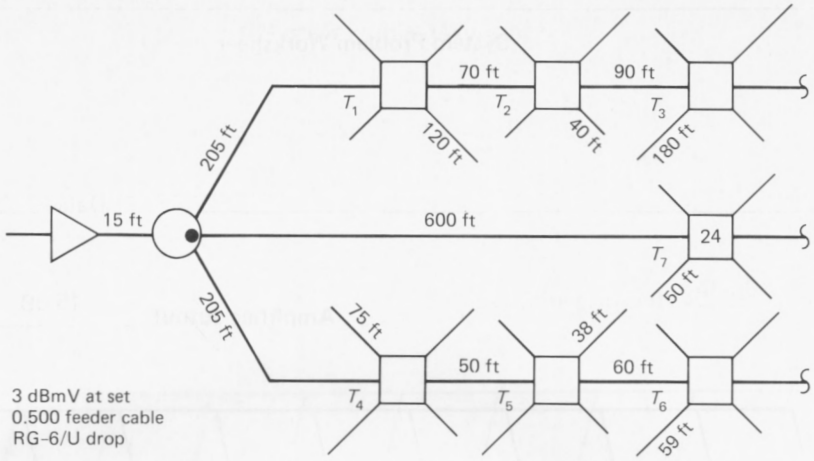


Fig. 8-6. System Problem 2.

into two, three, or four branches. The loss on each leg of a two-way splitter is 3.5 dB, that of a three-way is 3.5 dB on one leg and 7.0 dB on the other two, while the four-way splitter causes 7.0-dB loss on all four legs. Looking at Fig. 5-6 we can see that a three-way splitter has a dot to signify the leg of only 3.5-dB loss. In this example we have a three-way splitter whose low-loss leg goes to T_7 and is terminated.

Solution

In this Example, we first find the value of the amplifier. By referring to Fig. 8-1 we can see that the proper formula to use is

$$\text{Amplifier size} = \text{tap value} + \text{total losses}$$

Therefore, the value of the amplifier in Example 2 can be found by adding the loss of 615 ft of 0.500 cable, plus 3.5-dB loss through the splitter, plus the insertion of the 24-dB tap, plus the loss of 50 ft of type RG-6/U subscriber drop cable, plus the signal required at the TV set.

Placing all this in column 7 (for T_7) in Fig. 8-7, we see that the total loss of 40.95 dB would require a 41-dB amplifier to offset it. Now that you have found the value of the amplifier, determine the value of taps T_1 to T_6. Check your answer with those in Fig. 8-8.

Example 3

In this example (Fig. 8-9) we encounter a device known as a *directional coupler, DC*. The directional coupler is a device that allows us to redirect (couple) signals from the trunk cable to be fed to a length of feeder cable where multitaps will be inserted (cut in) into the cable and a small number of subscribers served. As we can see, there are three directional couplers, each with two (2) four-way taps on their respective runs. Also, notice that both trunk and feeder lines are terminated so that reflections of signal are eliminated.

Solution

For purposes of this example, we will assume that directional couplers have only 1 dB of loss in the through leg and that the value of attenuation in the other leg will vary with the amount of loss that we wish to insert depending on the needs of the system. Therefore, in a problem such as this, the attenuation value of the directional couplers loss must be found first. This is accomplished by finding the total loss in that leg, minus the known losses.

The following formula applies:

$$DC = \text{amplifier} - \text{known losses}$$

where the known losses are trunk cable losses, feeder-cable losses, drop-cable losses, insertion loss of the tap, signal at the subscriber's TV set, and multitap attenuation values.

When entering this information on the worksheet (Fig. 8-10), we will first list the total distribution cable losses (trunk + feeder) in the feeder-cable block under column 2. The reason for using column 2 is because tap 2 is part of the first branch:

$$\begin{aligned} \text{Trunk cable} &= 1.5 \times 0.90 = 1.35 \text{ dB} \\ \text{Feeder cable} &= 2.3 \times 1.31 = \underline{3.01 \text{ dB}} \\ \text{Total cable losses} &= 4.36 \text{ dB} \end{aligned}$$

Then it follows that

1. The drop cable loss = $4.75 \times 1 = 4.75$ dB
2. Tap insertion = 0.9 dB for tap 1 and 2.00 dB for tap 2
3. TV signal = 4 dB (given)
4. Tap value = 12 dB (given)

Adding these values together, we obtain a value of 28.01 dB for the known losses. Substituting in the formula, we obtain

$$\begin{aligned} DC &= \text{amplifier} - \text{known losses} \\ &= 45 - 28.01 = 16 \text{ dB} \end{aligned}$$

System Problem Worksheet

Student name _____ Date _____

Amplifier output 41 dB

Tap No.	Feeder Cable	Drop Cable	Tap Insertion	TV Signal	Splitter Loss	Directional Coupler	DC Insertion	Tap Value	Total Losses	Tap Size
1										
2										
3										
4										
5										
6										
7	8.05	2.00	0.40	3.00	3.50	–	–	24	40.95	
8										
9										
10										
11										
12										
13										
14										
15										
16										

Fig. 8-7. Partial solution To Problem 2.

System Problem Worksheet

Student name _____ Date _____

Amplifier output 41 dB

Tap No.	Feeder Cable	Drop Cable	Tap Insertion	TV Signal	Splitter Loss	Directional Coupler	DC Insertion	Tap Value	Total Losses	Tap Sizes
1	2.88	4.80	0.80	3.00	7.00	–	–	–	18.48	22
2	3.80	1.60	1.20	3.00	7.00	–	–	–	16.60	24
3	4.97	7.20	2.10	3.00	7.00	–	–	–	24.27	16
4	2.88	3.00	0.40	3.00	7.00	–	–	–	16.28	24
5	3.53	1.52	0.80	3.00	7.00	–	–	–	15.85	25
6	4.32	2.36	1.20	3.00	7.00	–	–	–	17.88	23
7	8.05	2.00	0.40	3.00	3.50	–	–	24	40.95	
8										
9										
10										
11										
12										
13										
14										
15										
16										

Fig. 8-8. Solution to Problem 2.

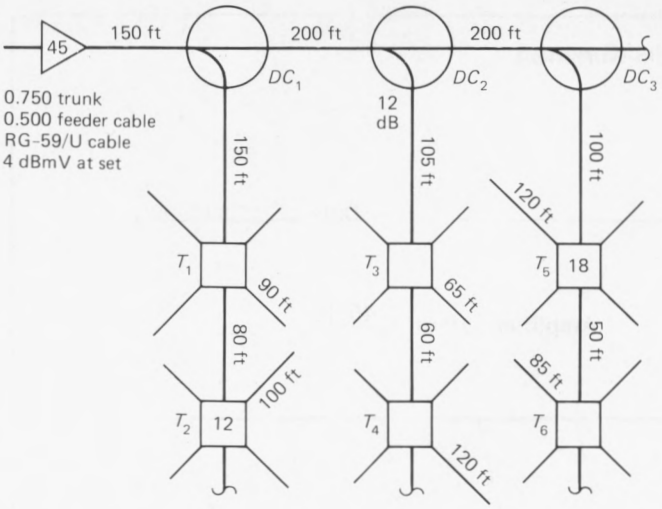


Fig. 8-9. System Problem 3.

(Remember to drop this fraction.) Inserting this in column 2 of the worksheet, we find that the total losses including the directional coupler is equal to the value of the amplifier. Continue with the problem and check your answers in Fig. 8-11.

NOTE Since the signal has not gone through DC_1, there is no directional coupler insertion loss.

SYSTEM MAPS

A system map is a drawing of a portion of the cable system showing distances, locations, and signal levels. Shown on system maps are the length in feet between amplifiers, power supplies, directional couplers, and multitaps. Because each foot of cable represents a loss in signal, accuracy is very important. To avoid confusion, symbols are used to represent the various components of the cable system. A list of the more common map symbols are found in App. C.

Because the technician will be using these maps for troubleshooting, a good understanding of these symbols is essential. Symbols are a simple, graphic representation of the actual object and are not meant to be the object in miniature.

In Fig. 8-12 we can see the layout of a portion of a cable system complete with poles, amplifiers, taps, and the distances between them. In Fig. 8-13 we see only the cable, amplifiers, splitters, and directional couplers. Obviously if we had trouble on the system, a map such as that shown in Fig. 8-13 would help us follow the main paths of signal flow. On the other hand, a map such as the one shown in Fig. 8-12 will help us follow the signal from tap to tap.

All maps are drawn to scale. The term *scale* means that a dimension on the map must be in proportion to the true dimension of the object. Map symbols are not drawn to scale. The more common scales used in the cable industry are 1 in. = 100 ft and 1 in. = 200 ft. Head-end or apartment house cable layouts are referred to as *drawings* and not *maps*.

Map Reading

Using Fig. 8-12, let us look at that portion of the system that shows the head-end and parts of (1) Federal Highway 45, (2) Pine Street, (3) Mahogany Street, (4) Chestnut Street, (5) Redwood Street, (6) Cedar Lane, (7) Palm Lane, (8) Plywood Court, (9) Oak Avenue, and (10) Maple Street.

Now let us follow one of the main signal paths from head-end to termination.

The signal leaving the head-end travels northwest 240 ft and enters a two-way splitter. The signal divides, going southwest to another part of the system and northeast along Main Street. Following the leg going northeast, we come to a four-way tap having 11 dB of attenuation. This tap is 130 ft from the splitter. Continuing another 130 ft, we come to a manual gain amplifier. The signal is filtered, amplified, and sent past four (4) four-way taps to an 8-dB directional coupler 590 ft away. At this point, a portion of the signal, 8 dB lower than that of the main line, is sent south. Continuing 220 ft northeast, we go past a 17-dB tap and arrive at a 12-dB directional coupler. Moving east 270 ft, we come to another amplifier. This amplifier, like the previous one, is a manual gain amplifier. Leaving the amplifier, we enter a three-way splitter. The low-loss leg continues east while the other legs go north and south to provide signals to subscribers on Oak Avenue and Mahogany Street. Following the low-loss leg an additional 350 ft, we find ourselves at another three-way splitter. Again we have legs that go north and south to supply subscribers between Mahogany and Chestnut Streets. Continuing east on the low-loss leg, we arrive 240 ft later at the third directional coupler in this line. At this point the signal is coupled to a line running north which enters a manual gain amplifier. Continuing east, we arrive at another amplifier 270 ft from the directional coupler. Then 60 ft later we enter a fourth directional coupler that couples a signal north for 270 ft before going through a 20-dB tap. Proceeding along Maple Street, we head southeast until we meet a two-way splitter that has legs going north and south. Following the signal path south, we enter a two-way tap 210 ft from the splitter. Continuing another 140 ft, we come to an 11-dB four-way tap. The other side of this tap has a length of cable that has been terminated by a 75-Ω resistance. Notice that only one automatic-gain amplifier is shown in this portion of the system. Looking at Fig. 8-13, we see that it is 575 ft east of the head-end. With the use of Fig. 8-12, it can be seen between Oak Avenue and Mahogany Street, south of Maple Street.

Sketches

All workers involved in installation or maintenance of a cable system should be able to read and make simple sketches. Sketching saves a lot of time and also helps reduce errors resulting from misunderstanding of verbal instructions. Most

System Problem Worksheet

Student name _____ Date _____

Amplifier output 45 dB

Tap No.	Feeder Cable	Drop Cable	Tap Insertion	TV Signal	Splitter Loss	Directional Coupler	DC Insertion	Tap Value	Total Losses	Tap Size
1										
2	4.36	4.75	2.90	4.00	–	16.00	–	12	44.01	
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										

Fig. 8-10. Partial solution to Problem 3.

System Problem Worksheet

Student name _____ Date _____

Amplifier output 45 dB

Tap No.	Feeder Cable	Drop Cable	Tap Insertion	TV Signal	Splitter Loss	Directional Coupler	DC Insertion	Tap Value	Total Losses	Tap Size
1	3.31	4.27	0.90	4.00	–	16.00	–	–	28.48	16
2	4.36	4.75	2.90	4.00	–	16.00	–	12	44.01	
3	4.52	3.08	0.90	4.00	–	12.00	1.00	–	25.50	19
4	5.31	5.70	1.80	4.00	–	12.00	1.00	–	29.81	15
5	6.26	5.70	0.90	4.00	–	8.00	2.00	18	44.86	
6	6.91	4.03	1.80	4.00	–	8.00	2.00	–	26.74	18
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										

Fig. 8-11. Solution to Problem 3.

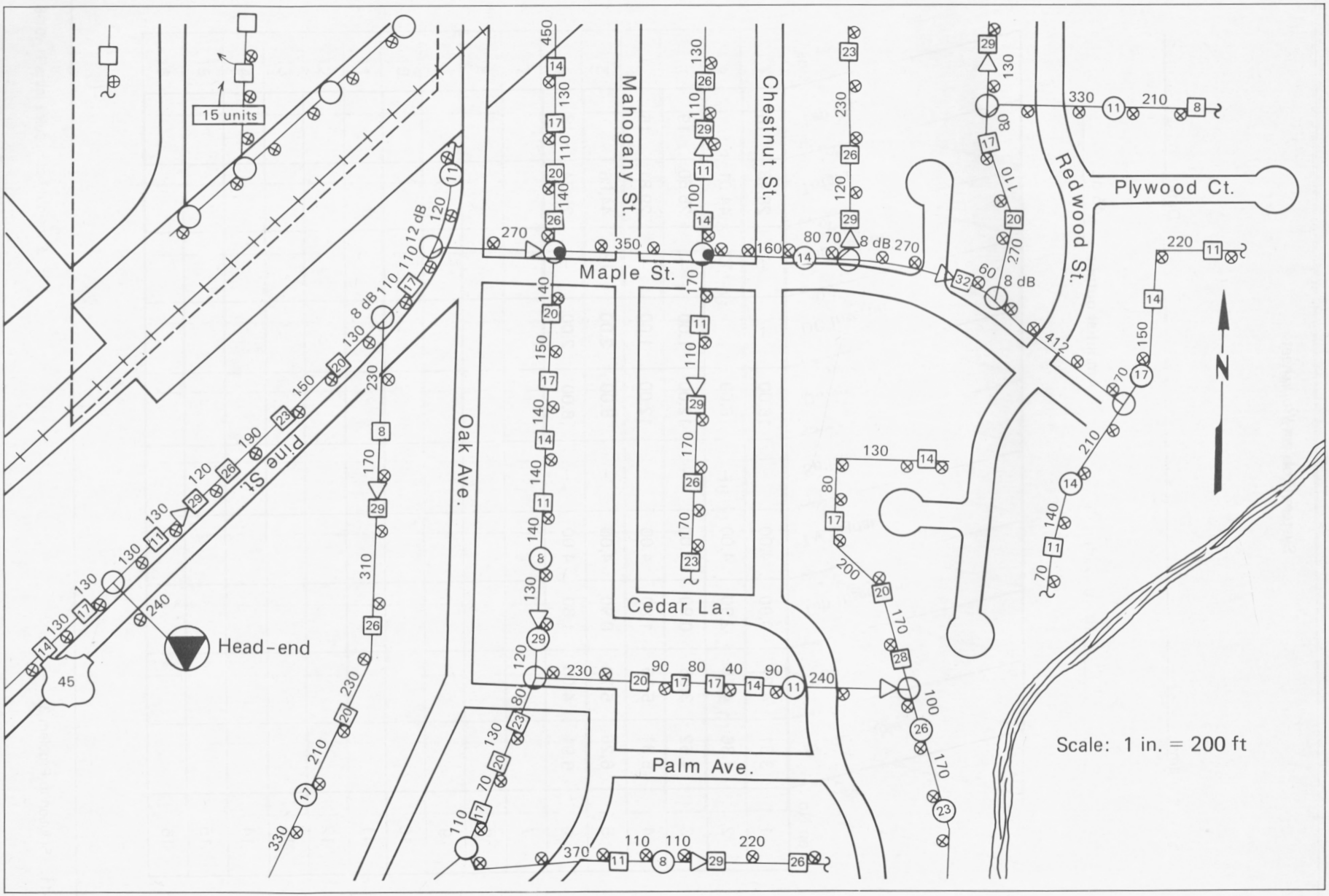


Fig. 8-12. Detailed system map.

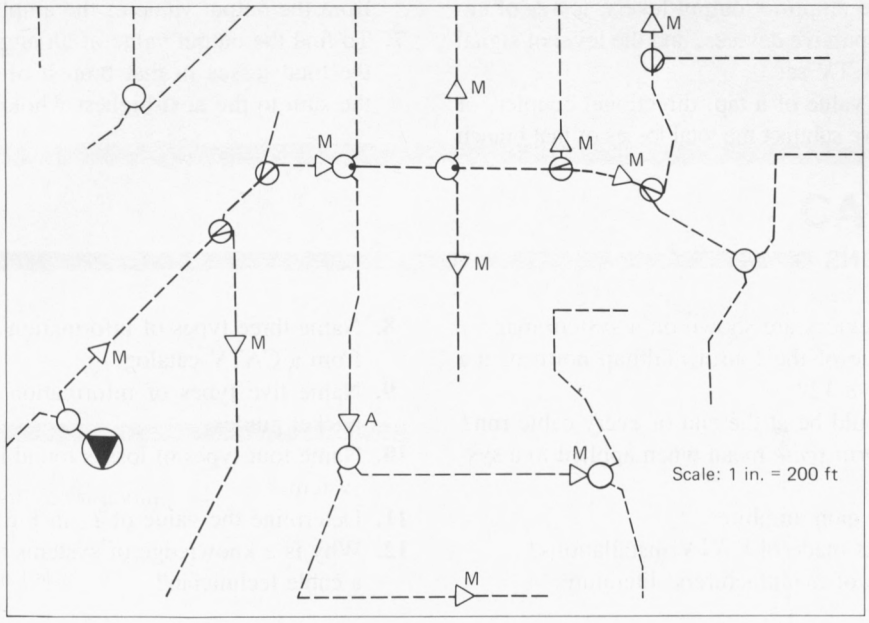


Fig. 8-13. Main signal paths.

cable companies require that a sketch of all subscriber installations be attached to the work order.

Sketches are done freehand and should contain the dimensions of the object being sketched. Even though the sketches themselves are not done to scale, they are drawn in proportion to their physical dimensions. To produce proportionally correct sketches without the use of tools (other than pencil and paper), do them on cross-section (grid) paper. Each grid provides a built-in scale to sketch by. Therefore, if an object (such as a driveway) is 20 ft long × 6 ft wide, you can sketch it as 20 grids long and 6 grids wide. In this manner, your sketch remains in proportion to the object being drawn.

Your sketch should contain all the information needed by the reader of your sketch. If subscriber cable is buried, it is very helpful for the installer, who might have to remove the drop at a later date, to locate it accurately. If the location of the cable is known from the location of landmarks such as trees, fences, or other structures, there will be no need to destroy a lawn searching for the cable.

MANUFACTURERS' LITERATURE

Manufacturers' literature is the printed material that is received with a product, handed out at conventions and sales promotions, or received in the mail. Manufacturers' literature falls into one or more of the following categories:

- *Brochures*—pamphlets or booklets featuring a single product and giving information about that product.
- *Flyers*—generally single-page advertisements featuring one or more items being offered at a special price. Flyers also give information on products being included or removed from inventory by the manufacturer.
- *Instruction sheets, tags, or labels*—one- or two-paged documents accompanying the item and giving instruction in assembly or alignment of the product. Also included in this category are caution tags and warning labels.
- *Pocket guides*—may be either simple plastic-coated cards or multipaged booklets containing such items as tables, graphs, charts, alignment procedures, equations, specifications, and symbols.
- *Catalogs*—books or booklets containing descriptions, specifications, typical applications, and prices for a wide variety of products. Catalogs used in the cable industry feature the tools and devices used for both aerial and underground installations as well as auxiliary products and supplies.

SUMMARY

1. A system map is a drawing of a portion of the cable system showing the active devices, signal levels, values of passive devices, and lengths of cable between devices.
2. A sketch is a freehand drawing, generally of a specific installation, made by the technician.
3. Manufacturers' literature includes brochures, flyers, instruction sheets, tags, pocket guides, and catalogs.
4. Catalogs give information about products such as specifications, prices, characteristics, exploded views, and applications.
5. In systems analysis, a portion of a cable system is ana-

lyzed to determine amplifier output levels, losses of cable, the values of passive devices, and the level of signal at the subscriber's TV set.

6. To determine the value of a tap, directional coupler, or total attenuation, we subtract the total losses of that branch from the output value of the amplifier.
7. To find the output value of an amplifier, we simply add the total losses in that branch of the system and raise the sum to the next-highest whole number.

REVIEW QUESTIONS

1. What types of devices are shown on a system map?
2. What is the value of the fourth multitap north of the head-end in Fig. 8-12?
3. What device should be at the end of every cable run?
4. What does the term *scale* mean when applied to a system map?
5. Define a manual gain amplifier.
6. Why are sketches made of CATV installations?
7. Name four types of manufacturers' literature.
8. Name three types of information that may be obtained from a CATV catalog.
9. Name five types of information found in multipaged pocket guides.
10. Name four types of losses found in a section of a cable system.
11. Determine the value of T_3 in Fig. 8-14.
12. Why is a knowledge of systems analysis invaluable to a cable technician?

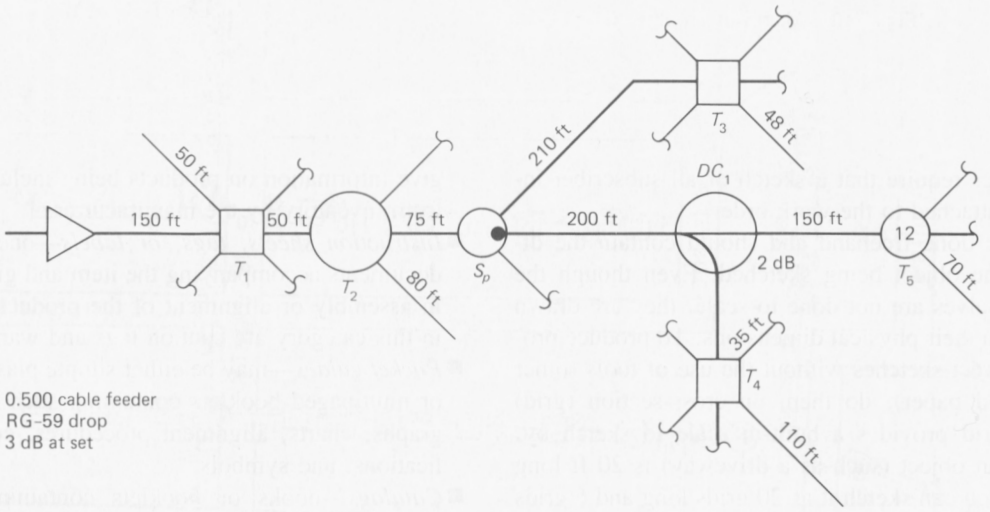


Fig. 8-14. Review Question 8-14.

9
CHAPTER
CATV TOOLS

INTRODUCTION

In this chapter you will learn about:

1. Cable hand tools
2. Cable construction tools
3. Cable power tools
4. Cable safety equipment

Only a brief description of each type of tool is supplied so that a wider variety may be covered. The safety equipment used in the construction, installation, and servicing of a cable system is also discussed.

It has been said that the proper tools can change the most unskilled workers into competent technicians. After reading this chapter the technician should know most of the specialized tools and safety equipment used in CATV work.

HAND TOOLS

A hand tool may be defined as any instrument used in a profession that does not require an external power source for its operation. Some of the more common hand tools used in the CATV industry are described in the paragraphs that follow.

Measuring Tools

A measuring tool is a device used to determine length, height, width, or distance. Two of the measuring tools that cable technicians use are the measuring stick and the measuring wheel.

Measuring Stick

The measuring stick is a 25-ft, insulated, telescoping, fiberglass tube with a hook on one end. It is used to measure the clearance between the various conductors on the pole as well as their heights above the ground. During use, sections are withdrawn and locked in place until the approximate height of the conductor is reached. The hook is then placed over the conductor. The height of the conductor is found by reading the scale that is printed on the sections. A measuring stick is shown in Fig. 9-1.

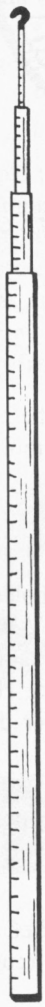


Fig. 9-1. Measuring stick.

Measuring Wheel

A measuring wheel is used to measure distances for mapping and construction purposes. To measure off a distance, an indicator is first set to zero and then placed against the wheel. As the wheel rotates, the distance covered by the wheel is shown on the indicator. A measuring wheel is shown in Fig. 9-2.

Fig. 9-2. Measuring wheel (*M/A Com Comm-Scope*).

Hand Boring Tools

The boring tools used in the construction and installation of coaxial cable include a tool called a *brace* and various *bits*.

Bits

A bit is a tool that bores holes in soft material. The two types of bits used in CATV work are the bell-hanger bit and the pole bit. The bell-hanger bit has a straight shank and is 12 to 24 in. in length. The bell-hanger bit is used in the installation of subscriber drop cable. The bell-hanger bit is shown in Fig. 9-3.

The pole bit is a spiral-shaped bit that is used to drill holes in wooden poles. The pole bit is shown in Fig. 9-4.

Brace

The brace is a tool that is used to hold the bit as well as to rotate it so that it can bore (cut) into the wood. A typical brace used in CATV work is shown in Fig. 9-5. Braces are used both in the construction of the cable system and for the installation of drop cable in a subscriber's home. The average length of a brace used in CATV work is 16 in. with a swing of 10 in. To use the brace, place the head (round wooden piece) in the palm of one hand and rotate the handle with the other.

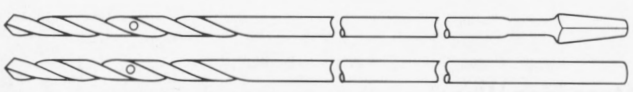


Fig. 9-3. Bell hanger bit (*CWY Electronics*).

Fig. 9-4. Pole bit (*M/A Com Comm-Scope*).

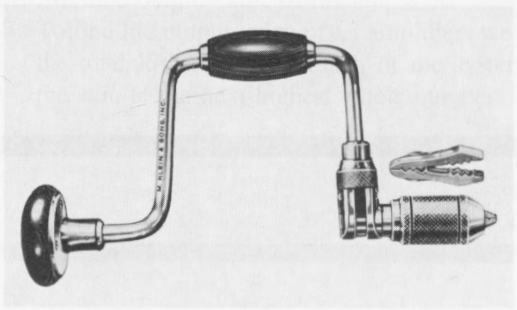


Fig. 9-5. Brace (*Klein Tools, Inc.*).

Tightening Tools

Tightening tools are used to loosen or tighten bolts, screws, or nuts. One type of tightening tool used in the cable industry for this purpose is the wrench.

A wrench is a tool that either fits over or slips onto a nut or bolt head. The wrench most commonly used by CATV workers is the lineman's wrench. The lineman's wrench has four openings to fit the different-sized bolts and nuts used in CATV construction work. Figure 9-6 shows a lineman's wrench.

Striking Tools

A striking tool is defined as a weight attached to a handle that is used to deliver a blow to another object. The tool that fits this description best is the *hammer*. In cable work the most frequently used hammers are the:

1. *Lineman's (straight claw) hammer*—used to open cable reels, drive nails, or remove large staples from poles. A lineman's hammer is shown in Fig. 9-7.
2. *Hand drilling hammer*—used for heavy-duty work such as driving pole steps. Figure 9-8 shows a hand drilling hammer.
3. *Soft-faced hammer*—used to strike surfaces that a hammer with a hard face would damage. Soft-faced hammers are used on such items as amplifier housings or pedestal covers. A soft-faced hammer is shown in Fig. 9-9.

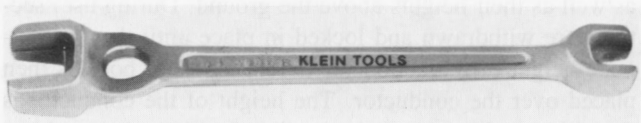


Fig. 9-6. Lineman's wrench (*Klein Tools, Inc.*).

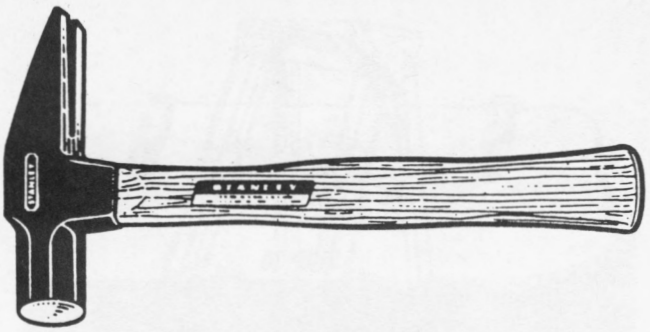


Fig. 9-7. Lineman's hammer (*Stanley Tools*).

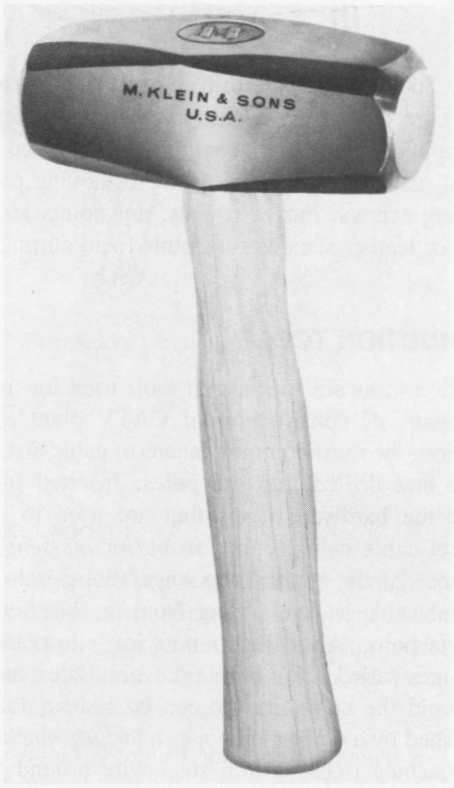


Fig. 9-8. Hand drilling hammer (*Klein Tools, Inc.*).

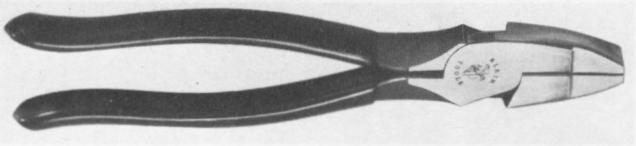


Fig. 9-10. Lineman's pliers (*Klein Tools, Inc.*).

Gripping Tools

A gripping tool is a tool whose main function is to hold or grip materials. One of the gripping tools used in the CATV field is lineman's pliers. A pair of lineman's pliers is shown in Fig. 9-10. Lineman's pliers are used to cut and bend wire as well as for general-purpose uses.

Cutting Tools

A cutting tool is a sharp-edged implement used to cut away material. It may also be composed of two surfaces that when brought together cut or shear the material placed between them. Two of the more common cutting tools found in the cable worker's toolbox are knives and cable cutters.

An electrician's knife (Fig. 9-11) is used to cut cable sheathes and strip insulation from conductors.

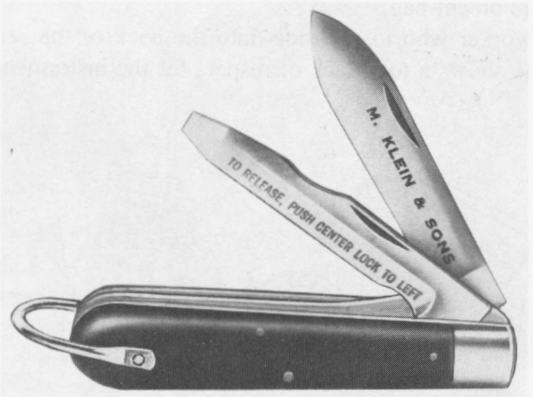


Fig. 9-11. Electrician's knife (*Klein Tools Inc.*).

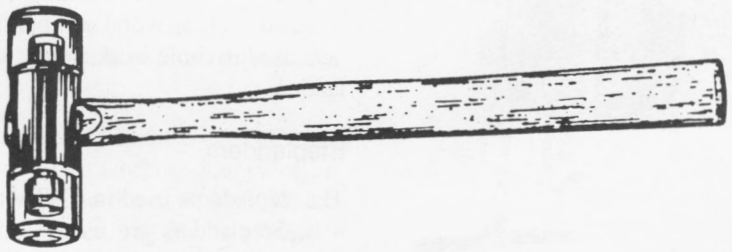


Fig. 9-9. Soft-faced hammer (*Stanley Tools*).

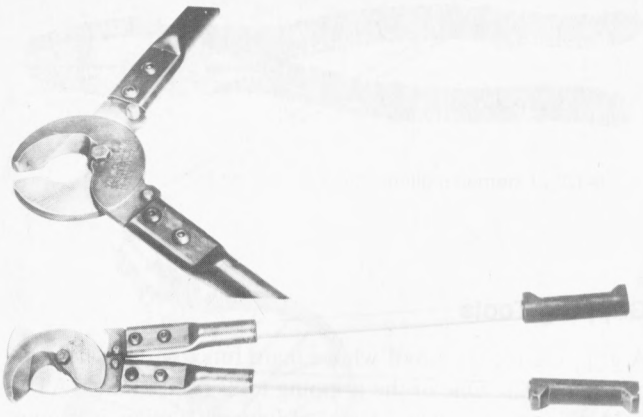


Fig. 9-12. Cable cutters (*Klein Tools, Inc.*).

Fig. 9-14. Equipment bag (*Klein Tools, Inc.*).

A cable cutter is shown in Fig. 9-12 and is used to cut the coaxial cable used in constructing a CATV plant.

Pouches and Equipment Bags

Toolboxes, pouches, and equipment bags are used to hold and protect the tools used in CATV. A tool pouch is a leather carrier that is attached to a belt into which various tools are carried by the worker. A tool pouch is shown in Fig. 9-13. An equipment bag is a canvas bag that holds the climbing equipment of the CATV worker. Figure 9-14 shows the equipment bag.

A worker who tosses tools into the back of the service vehicle shows a total lack of respect for the instruments of the trade. Tools, if they are to be of any value at all, must be taken care of properly. The proper care of hand tools includes application of a thin coat of oil on exposed surfaces to prevent rust or a few drops of oil to moving parts such as adjusting screws, movable jaws, and joints and use of oil paper or leather sheaths for pointed and cutting tools.

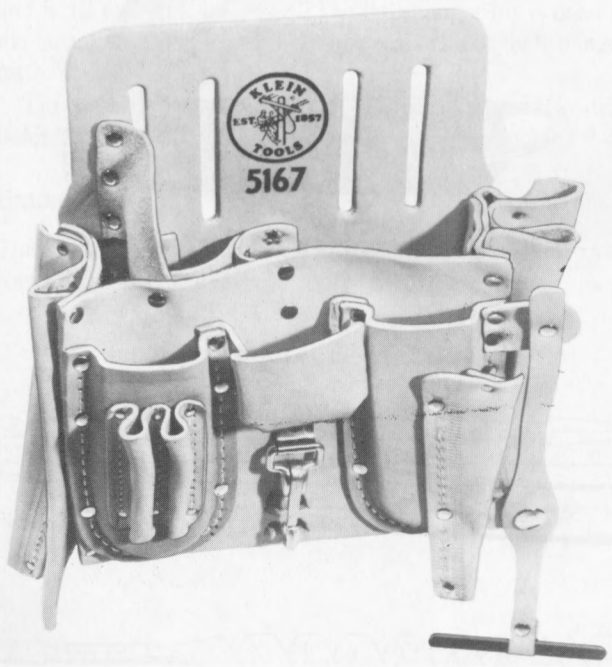


Fig. 9-13. Tool pouch (*Klein Tools, Inc.*).

CONSTRUCTION TOOLS

Construction tools are specialized tools used for the installation, repair, or construction of CATV plant. In aerial construction, the most common means of cable distribution, holes are first drilled into the poles. Inserted into these holes are the hardware items that are used to secure a ¼-in. steel cable called either *strand* or *messenger wire*. The purpose of the strand (messenger) wire is to support the coaxial cable as it is strung from the head-end to its termination point. After the strand wire is in place on the pole, devices called *cable blocks* (covered later) are placed on it to hold the cable until it can be lashed. Lashing is accomplished by a device known as a *lashing machine*. The lashing machine twists a thin steel wire around both the strand and the cable to secure them together.

Some of the construction tools used in CATV are described in the following paragraphs.

Ladders

Ladders used in CATV should be made of a nonconducting material such as wood or fiberglass. The two types of ladders used in cable work are the stepladder and the extension ladder.

Stepladders

The stepladders used in CATV are seldom higher than 6 to 8 ft. Stepladders are used primarily in the installation of drop cable to a subscriber's home. Figure 9-15 shows a typical stepladder.

Fig. 9-15. Step ladder (*Anixter Bros., Inc.*).

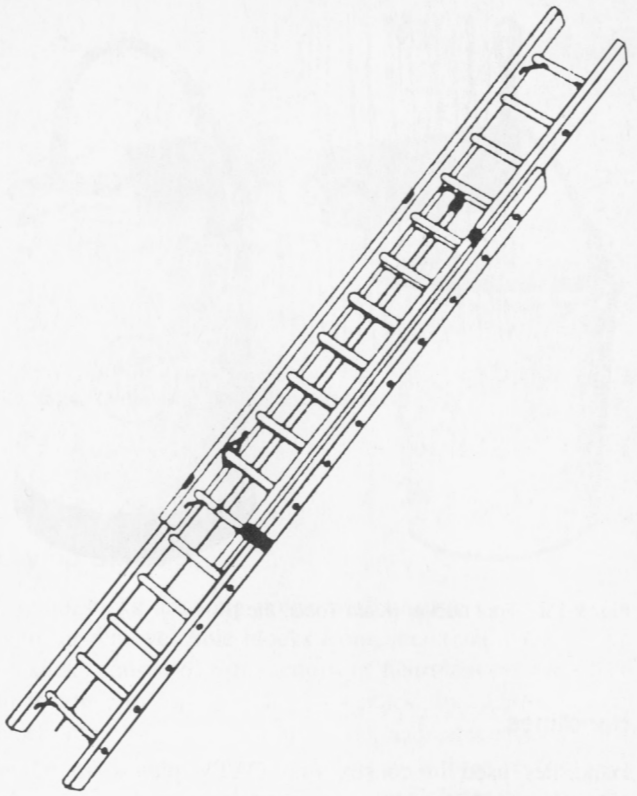


Fig. 9-16. Extension ladder (*M/A Com Comm-Scope*).

Extension Ladders

An extension ladder is a two-sectioned assembly with both pieces secured to each other. These sections slide onto each other to form a longer assembly. Extension ladders used in CATV have additional features not found on a standard ladder. Some of these features are:

1. *Strand hooks*. Strand hooks are U-shaped metal hooks that fit over the strand, thus preventing the ladder from falling.
2. *Safety shoes*. Safety shoes have two features that are important to the CATV technician: a nonslip surface on the bottom and the ability to be rotated so that they may dig into the surface on which the ladder is placed.
3. *Pole grips*. Pole grips are thin straps of nylon attached between the side rails at the top of the ladder. The strap allows the ladder to lean against a pole or corner of a building.

Standard lengths for extension ladders used in CATV are the 24-, 28-, and 32-ft sizes. The working length of an extension ladder is 3 to 4 ft less than the rated size. Figure 9-16 shows a typical extension ladder, and Fig. 9-17 shows some of the accessories available for extension ladders used for CATV work.

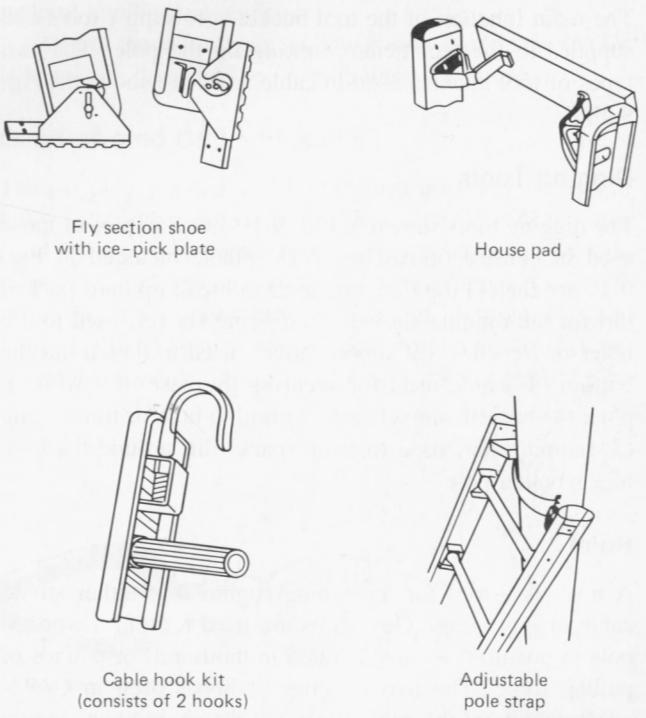


Fig. 9-17. Extension ladder accessories (*Anixter Bros.*).

Fig. 9-18. Tool bucket (*Klein Tools, Inc.*).

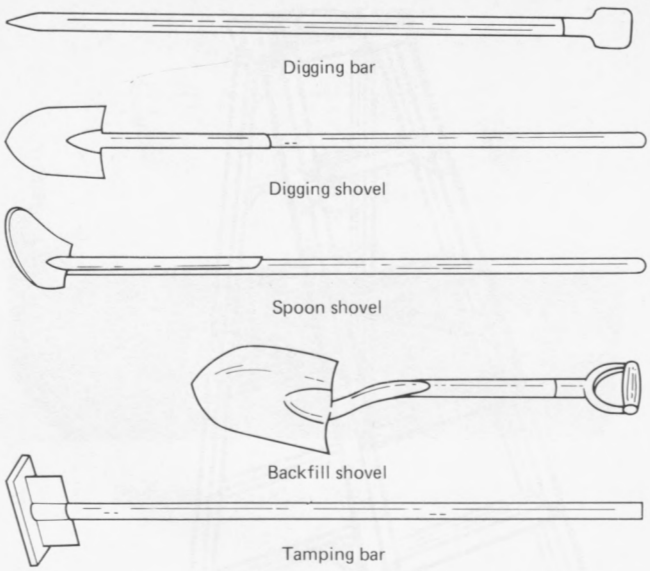


Fig. 9-19. Digging tools (*M/A Com Comm-Scope*); tamping bar (*Lemco Tools*).

Handlines

Handlines used in constructing CATV plants are 50 to 60 ft long and ¼ to ⅝ in. thick and are made of manila, nylon, or polypropylene. Generally both ends will be fitted with either clasps, rings, snaps, or hooks. A handline may be either pulleyed or nonpulleyed, depending on the application. In order to throw them long distances, through trees or brush, or over strand, padded weights are attached.

Tool Bucket

The main function of the tool bucket is to supply tools and supplies to the technician working on the pole. The two types of tool buckets used in cable work are shown in Fig. 9-18.

Digging Tools

The digging tools shown in Fig. 9-19 are examples of those used in construction of a CATV plant. Included in Fig. 9-19 are the (1) digging bar, used to break up hard-packed dirt for the digging shovel; (2) digging shovel, used to dig holes or trenches; (3) spoon shovel, used to flatten out the bottom of a hole used for securing the base of a wooden pole; (4) backfill shovel, used to refill a hole or trench; and (5) tamping bar, used to tamp (pack) dirt around the base of a wooden pole.

Hoist

A hoist is a tool for tensioning (tightening) either strand cable or guy wires. Guy wires are used to hold a wooden pole in position. A hoist is rated in thousands of pounds of pulling force. The two varieties of hoists used in CATV construction are the cable hoist and the chain hoist. Figure 9-20 shows a chain hoist.

Cable Blocks

A cable block is the device mentioned earlier that is hooked on the strand into which the coaxial cable is placed preparatory to lashing. A cable block is shown in Fig. 9-21.

Grips

Grips are used to hold or position either strand wire or guy wire while it is being tensioned. Two styles of grips are shown in Fig. 9-22.

Another type of grip, a *pulling grip,* is used to pull coaxial cable through cable blocks. The pulling grip is placed over the end of the coaxial cable and attached to a length of strand cable. The strand cable, which is much lighter, is placed into the cable block and is used to pull the coaxial cable through. When the pulling grip is stretched, the woven sides collapse around the cable and hold it fast. There are specific sizes of pulling grip for each size of coaxial cable. A typical pulling grip is shown in Fig. 9-23.

Pole Sling

The pole sling is a wide strap placed around a pole to provide for the attachment of handlines, hoists, or blocks. Figure 9-24 shows a pole sling.

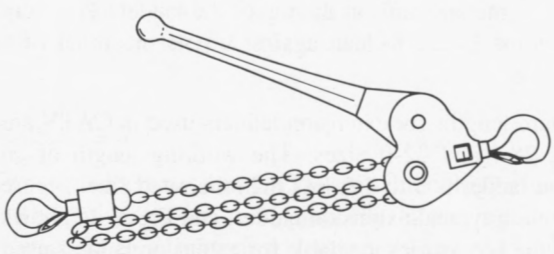


Fig. 9-20. Chain hoist (*M/A Com Comm-Scope*).

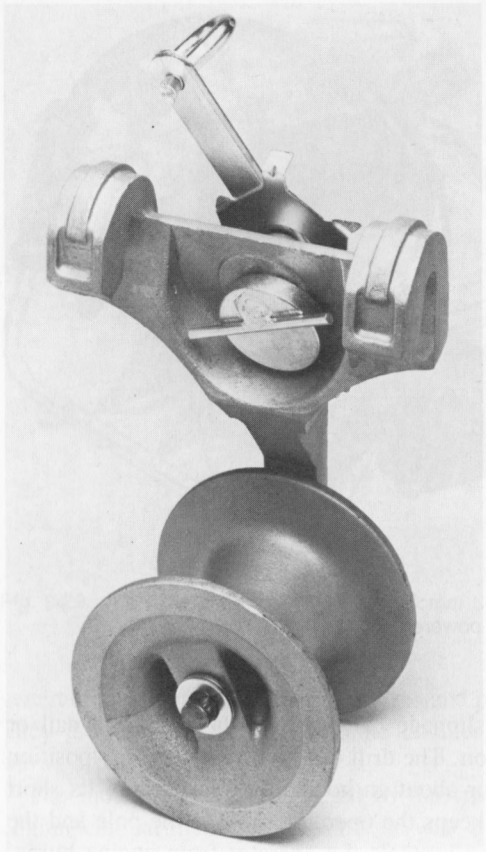


Fig. 9-21. Cable block (*Lemco Tools*).

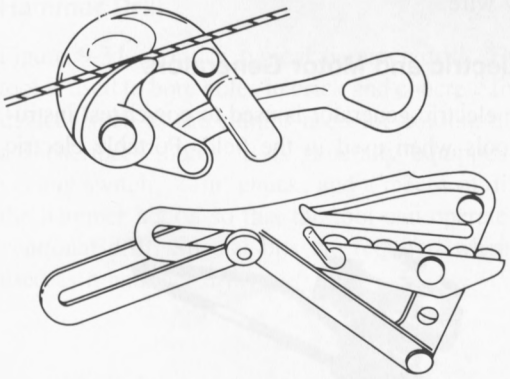


Fig. 9-22. Guywire grips (*M/A Com Comm-Scope*).

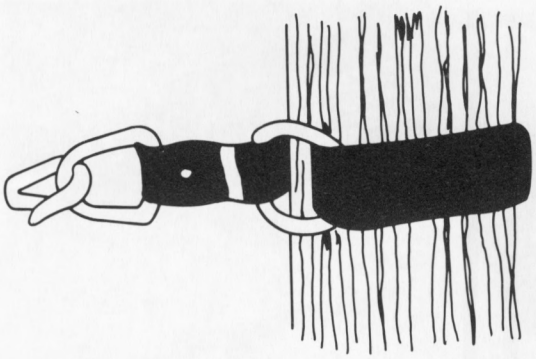


Fig. 9-24. Pole sling (*M/A Com Comm-Scope*).

Lay-up Sticks

Lay-up sticks are long poles used to install cable blocks onto, or remove cable blocks from, the strand cable. Lay-up sticks consist of 6-ft sections of fiberglass or wood that fit together to form 18- to 24-ft poles. In addition to the block-lifting head, wire raising, saw, and cable-raising heads are also available. Figure 9-25 shows a three-section lay-up stick. Figure 9-26 shows a cable block lifter that attaches to a lay-up stick.

POWER TOOLS

A power tool may be defined as any device whose source of energy is other than human labor. Such sources include air (pneumatics), fluids, (hydraulics), electric motors, and internal combustion engines.

Some of the more common power tools used in the CATV industry are described in the following paragraphs.

Gas-Powered Drill and Auger

The gas-powered drill is used by construction crews to drill holes in wooden poles. Since the drill works faster than hand drilling, more aerial footage may be obtained through its use. The drill operates at about 400 revolutions per minute (rpm) through a heavy-duty gearbox which provides a maximum torque (twisting force) to the bit. To ensure that the operator does not lose balance, a centrifugal clutch is pro-

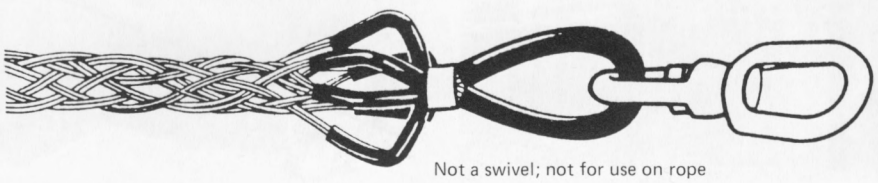


Fig. 9-23. Pulling grip (*Klein Tools, Inc.*).

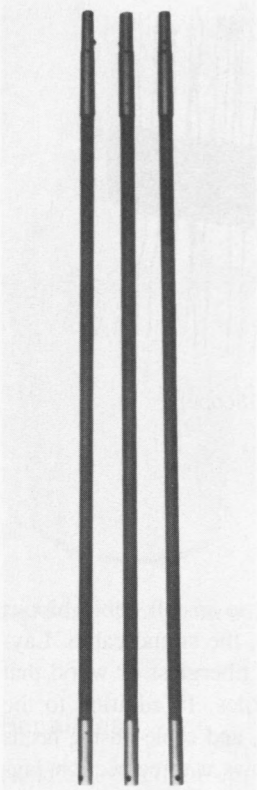


Fig. 9-25. A lay-up stick (*Lemco Tools*).

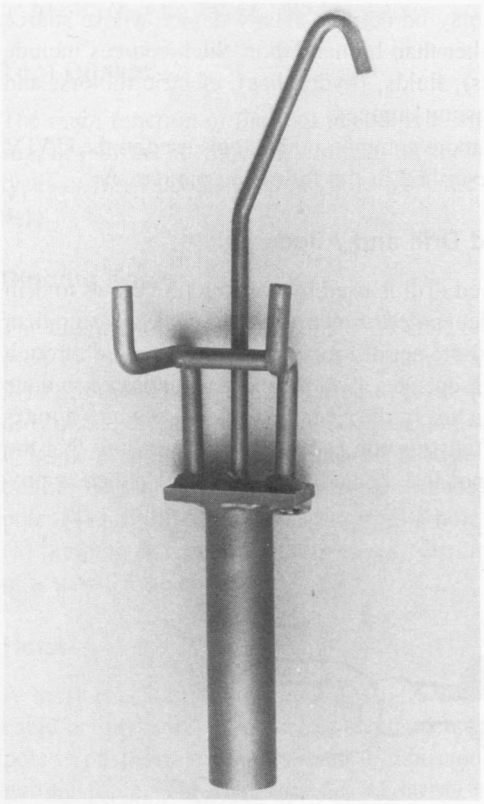


Fig. 9-26. Block lifter head (*Lemco Tools*).

Fig. 9-27. Gas-powered drill (*Lemco Tools*).

vided so that slippage can occur if the bit hits a nail or other obstruction. The drill can be operated in any position and will run for about an hour on a pint of fuel. Its short overall length keeps the operator close to the pole and the double-shielding protects the operator from engine burns. Figure 9-27 shows a gas-powered drill.

A tool similar to the gas-powered drill is the gas-powered auger. The gas-powered auger is used to make anchor holes and drive screw anchors into soft soil (Fig. 9-28). An anchor is a device that is buried in the ground and is used to secure a guy wire.

Portable Electric and Motor Generators

The portable electric generator is used to power test instruments and tools when used in the field. Portable electric

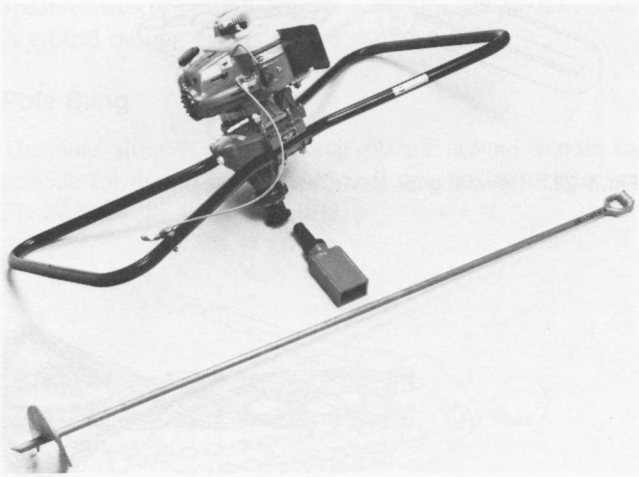


Fig. 9-28. Gas-powered auger, screw anchor, and anchor adapter (*Lemco Tools*).

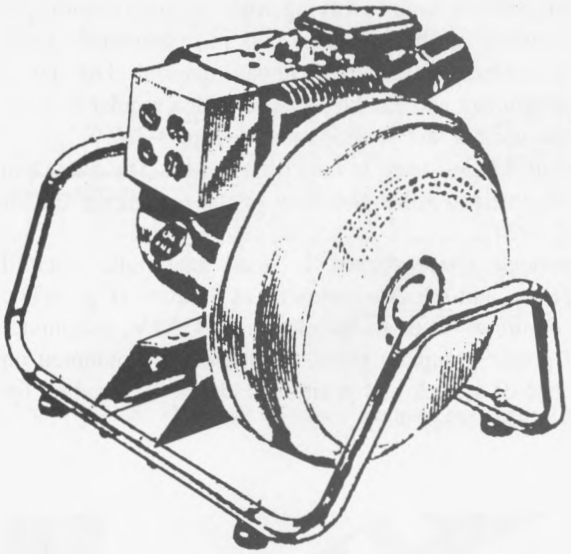


Fig. 9-29. Portable generator (*M/A Com Comm-Scope*).

generators are available in various sizes and power outputs. They are driven by small gasoline engines. Figure 9-29 shows a portable generator.

The motor generator is bolted to the frame inside the engine compartment of a CATV service truck and connected to the battery of the vehicle. The motor generator provides electrical power to tools and test equipment used by CATV service crews and technicians. The motor generator has a dc motor that drives an ac generator (Fig. 9-30).

Hammer Drill

Figure 9-31 shows a typical hammer drill. This versatile tool is used to bore holes in brick and concrete for anchoring devices such as the clamps used for holding drop cable to a subscriber's home. It is generally equipped with a reversing switch, 3/8-in. chuck, and a means of disconnecting the hammer action so that the tool can operate like a conventional drill. Special bits are required when the tool is used as a hammer drill.

Fig. 9-30. Motor generator (*Pacific Scientific*).

Fig. 9-31. Hammer drill (*CWY Electronics*).

Other Power Tools Used in CATV Work

These include the following:

1. *Concrete saw*—used to cut concrete or asphalt for laying underground cable. It is powered by either a gasoline or a diesel engine (Fig. 9-32).
2. *Sod cutter*—used to cut the sod (grass) along a proposed trench (Fig. 9-33). The size of the cut sod is approximately 1 in. in depth and 12 in. in width. After the trench is filled in, the sod is replaced.
3. *Trencher*—used to dig trenches as required. Trenchers are available in small walk-behind, tractor-mounted, and track-mounted models. They dig a variety of trench widths and depths. A typical trencher is shown in Fig. 9-34.
4. *Alligator chain*—used for digging into frozen ground, or for other difficult soil conditions. Figure 9-35 shows an alligator chain mounted on a tractor.

Fig. 9-32. Concrete saw (*Federal Mogul Corp. Target Products Division*).

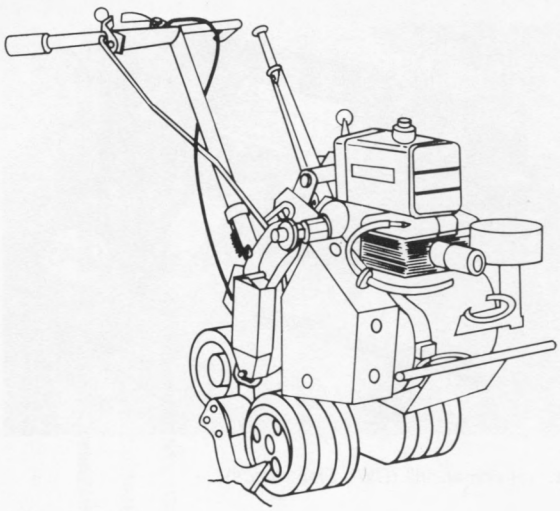


Fig. 9-33. Sod cutter (*Turfco Manufacturing Inc.*).

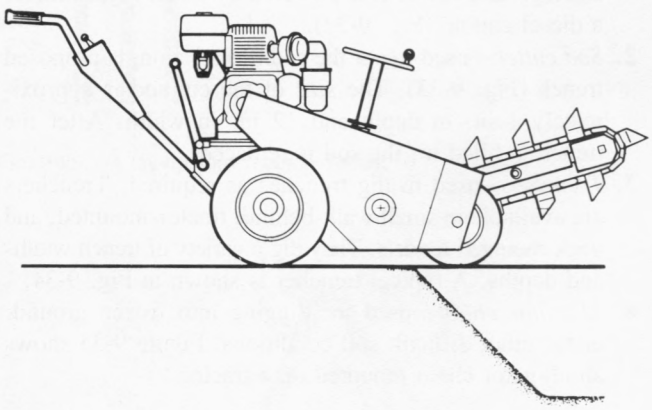


Fig. 9-34. Walk behind trencher (*M/A Com Comm-Scope*).

5. *Earth saw*—a large revolving wheel equipped with special carbide teeth that makes cuts in frozen earth, rock, coral, and most types of roadway material. The saw is an attachment and can be replaced with a regular trencher where normal soil is encountered (Fig. 9-36).
6. *Backfill blade*—used to backfill a trench. The blade can be mounted to either the front or the rear of the tractor (Fig. 9-37).
7. *Front-end loader*—used to load materials, backfill trenches, and relocate materials as required (Fig. 9-38).
8. *Earth auger*—used to bore holes for CATV, telephone, and power company poles. It is generally mounted on the bed of a truck and positioned above the location for a new pole (Fig. 9-39).

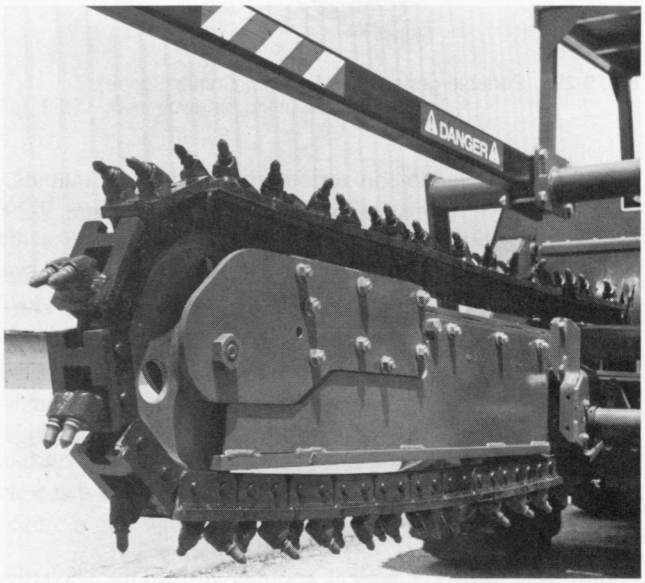


Fig. 9-35. Alligator chain (*Charles Machine Works*)

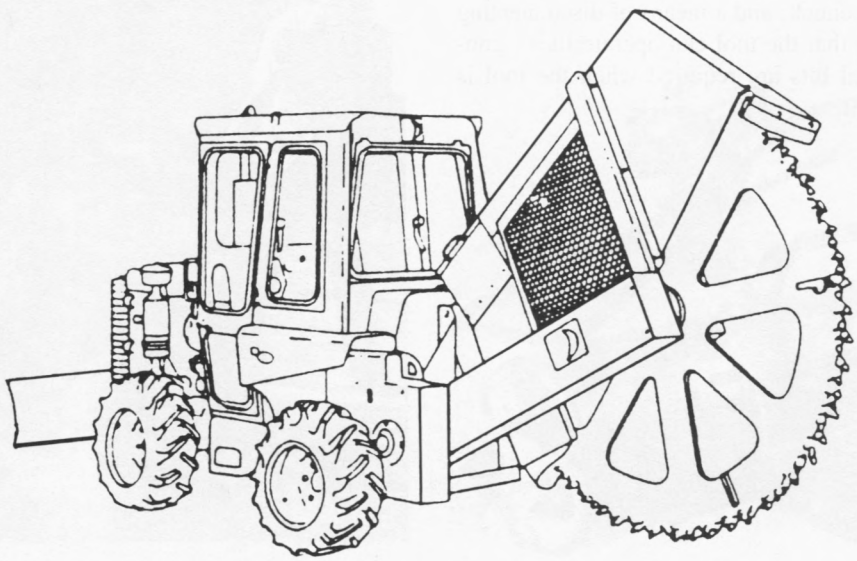


Fig. 9-36. Earth saw (*M/A Com Comm-Scope*).

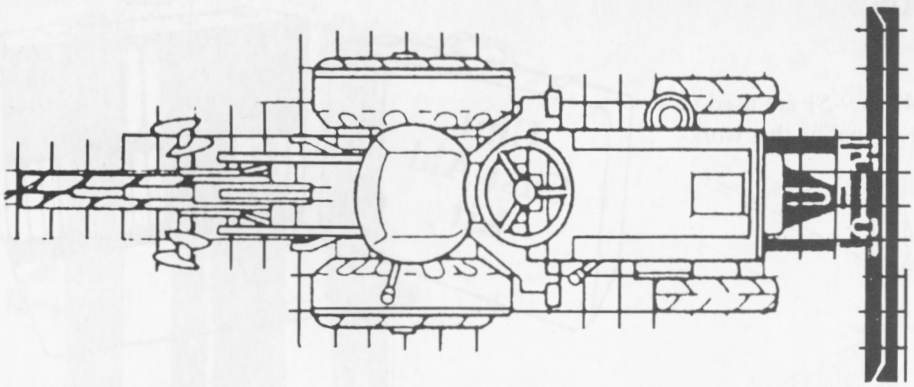


Fig. 9-37. Backfill blade on tractor mounted trencher (*M/A Com Comm-Scope*).

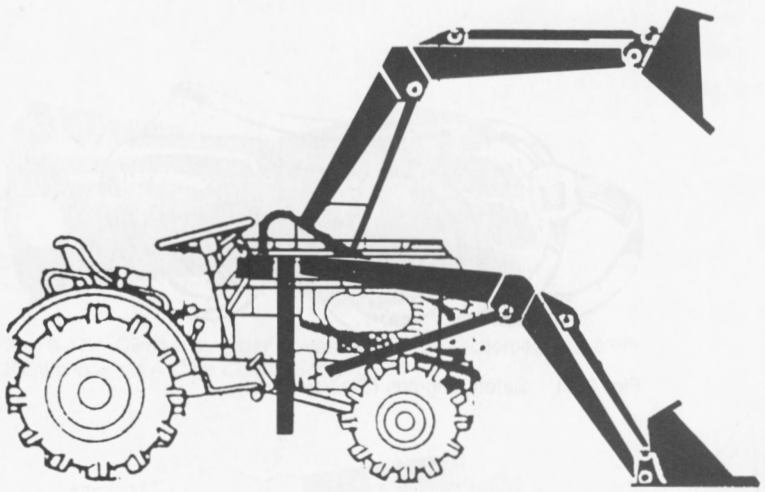


Fig. 9-38. Front-end loader (*M/A Com Comm-Scope*).

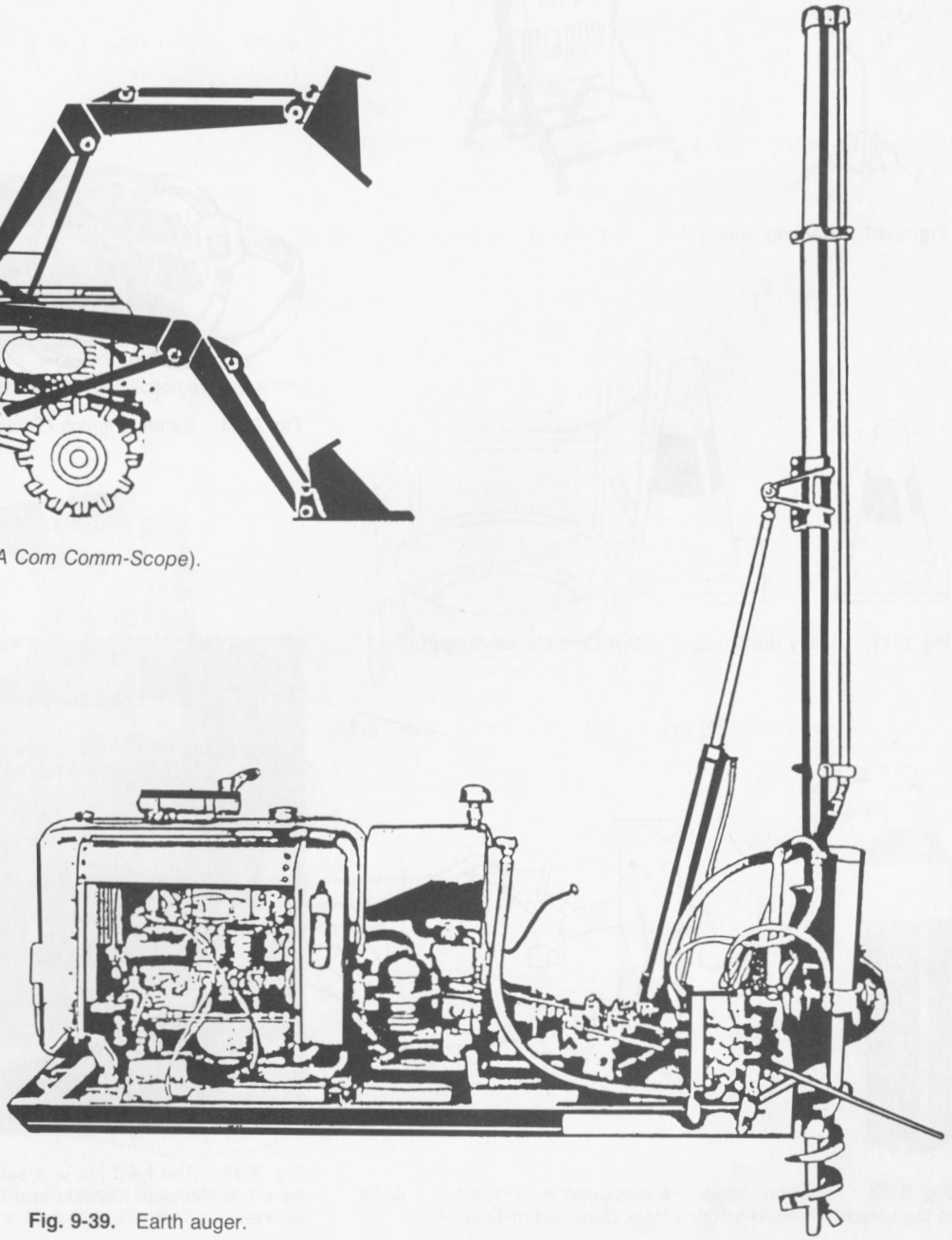


Fig. 9-39. Earth auger.

SAFETY IN CATV CONSTRUCTION

Safety Equipment

The safety devices shown in Figs. 9-40 to 9-51 are used to protect personnel as well as to inform the public that workers are present.

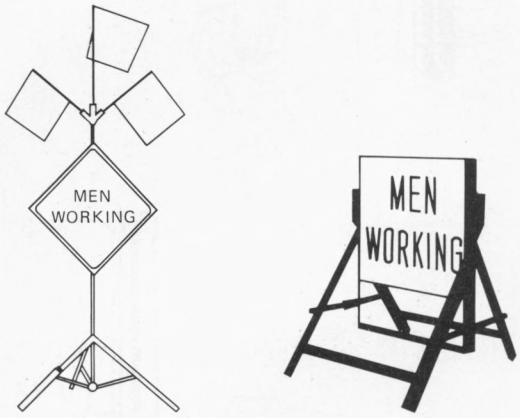


Fig. 9-40. Warning signs (*M/A Com Comm-Scope*).

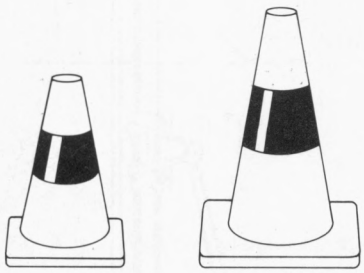


Fig. 9-41. Safety (traffic) cones (*M/A Com Comm-Scope*).

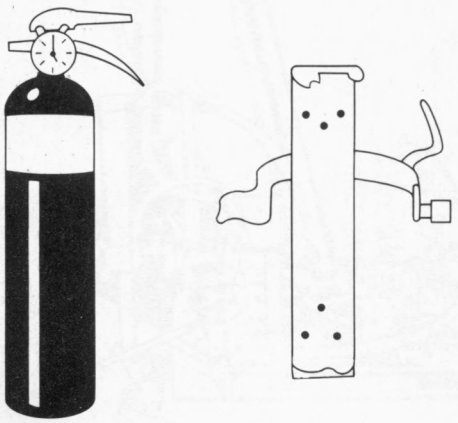


Fig. 9-42. A carbon dioxide fire extinguisher. This unit is installed in the vehicle for fire protection (*M/A Com Comm-Scope*).

Fig. 9-43. A first-aid kit of adequate size should be maintained in all vehicles and work areas (*M/A Com Comm-Scope*).

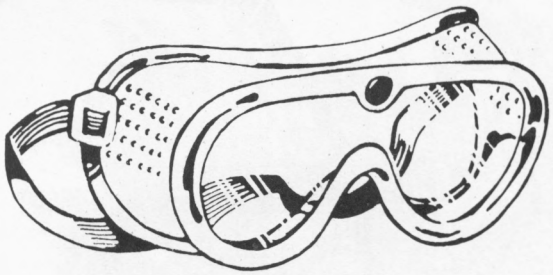


Fig. 9-44. Safety goggles (*Stanley Tools*).

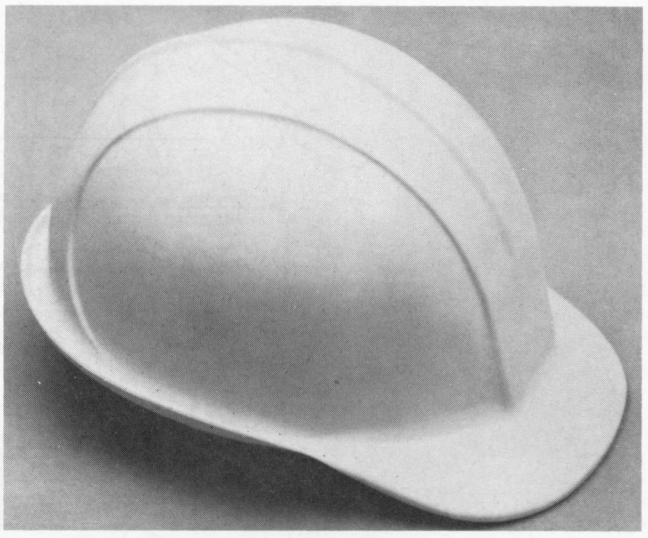


Fig. 9-45. The hard hat is a safety hat designed for persons exposed to electrical hazards and falling objects (*M/A Com Comm-Scope*).

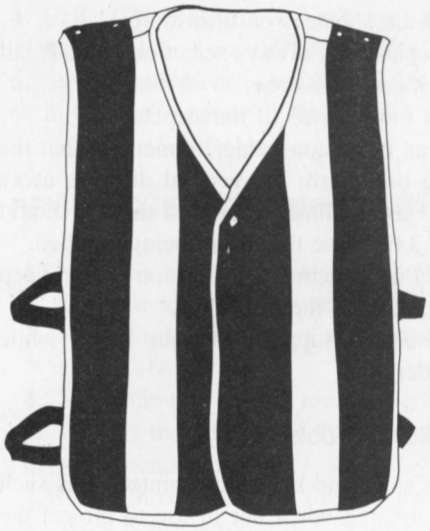


Fig. 9-46. Traffic vests should be worn for work near hazardous traffic areas (*M/A Com Comm-Scope*).

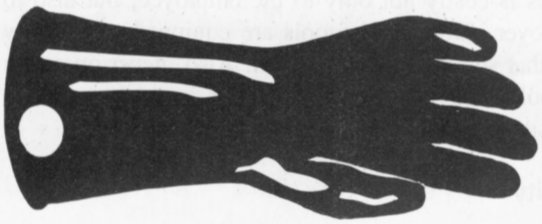


Fig. 9-47. Climber's rubber gloves will give protection against electrical shock (*M/A Com Comm-Scope*).

Fig. 9-48. Climber's protective gloves are worn over rubber gloves to protect them from damage (*M/A Com Comm-Scope*).

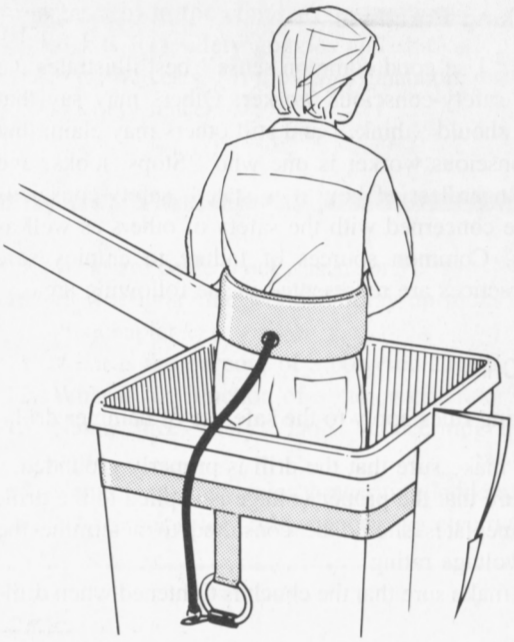


Fig. 9-49. Safety harness for the bucket of a bucket truck.

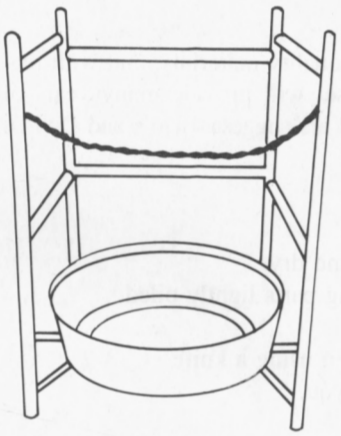


Fig. 9-51. Safety fence for manholes (*M/A Com Comm-Scope*).

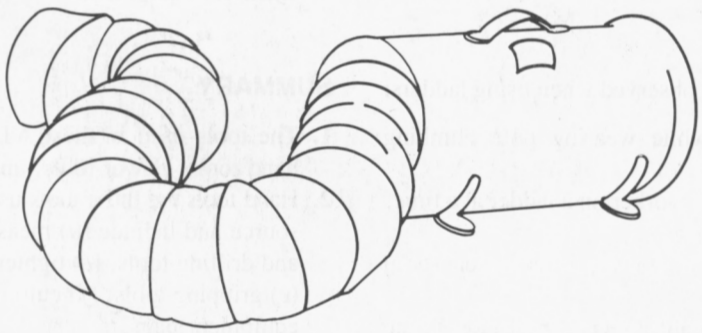


Fig. 9-50. A manhole ventilator is used to circulate fresh air into a manhole for crew members (*M/A Com Comm-Scope*).

Safe Working Practices

The phrase "Use good common sense" best illustrates the creed of a safety-conscious worker. Others may say that the worker should "think," and still others may claim that a safety-conscious worker is one who "Stops, looks, and listens." Regardless of how it is stated, safety-conscious workers are concerned with the safety of others as well as themselves. Common sources of failure to employ safe working practices are represented in the following areas.

Hammer Drills

The following rules apply to the safe use of hammer drills:

1. Always make sure that the drill is properly grounded.
2. Make sure that the proper voltage is applied to the drill. The nameplates should be consulted to determine the proper voltage rating.
3. Always make sure that the chuck is tightened when drilling.
4. Never work in wet locations with a hammer drill.
5. Never allow the drill to overheat due to excessive loading.
6. Never use a hammer drill without wearing safety glasses.

Knives

A knife is made with high-quality materials, and with reasonable care and proper use, will provide many years of service. The following items are suggested Do's and Don't's when working with knives.

Do's

1. Keep your knife clean and dry.
2. Keep blades and working parts lightly oiled.
3. Keep blade(s) sharp.
4. Wear safety glasses when using a knife.
5. Always cut away from you.

Don't's

1. Don't use a knife as a lever or pry bar.
2. Don't use a knife as a hammer.
3. Don't throw the knife; rather, hand it to a fellow worker.

Ladders

The following rules should be observed when using ladders:

1. Never climb a ladder while wearing pole climbing equipment.
2. Never have more than one worker on a ladder at a time.
3. Climb carefully, never hurry.
4. Extend the strand hooks if you are working on aerial cable.
5. When working on aerial cable, secure the ladder to the strand by wrapping a length of rope around a rung and the strand.
6. Make sure that the ladder is on firm footing.
7. When using stepladders, always select one that is tall enough to reach the work area.
8. Never stand on the top step of the stepladder.
9. When placing an extension ladder, remember that the base should be one-fourth the vertical distance away from the object to be climbed and that the top should extend at least 3 ft above the object being climbed.
10. When extending or retracting an extension ladder, keep your hands and feet off the rungs.
11. Never carry tools or supplies in your hands while climbing a ladder.

Hand Tools and Power Tools

Sharp tools such as saws and knives or pointed tools such as awls should be covered when not in use to protect the worker from cuts and punctures. All sharp or pointed tools should be kept in either the tool pouch or toolbox.

Power tools, when misused, can cause loss of life, limb, or livelihood. The amount of time lost on the job as a result of injuries is costly not only to the employee, but also to the employer. Most power tools are equipped with safety features that should not be defeated. Also, *never* operate a power tool when you are tired, ill, or in doubt as to its proper use and limitations.

Electricity

The safety rules and practices designed to prevent accidents while working around electricity are:

1. Always treat electrical wiring as being potentially dangerous.
2. Although an electrical shock may not be fatal, it might startle or frighten you. If this were to happen, it could cause serious injury.
3. Do not touch a grounded surface while working on electrical equipment to which power is applied.
4. Be sure to read and follow all instructions supplied with electrical or electronic equipment before attempting to use it.
5. Always disconnect equipment that does not appear to be operating properly.
6. Do not wear rings or watches when working around live electrical equipment.

SUMMARY

1. The tools used in the CATV industry are classified as hand tools, power tools, and construction tools.
2. Hand tools are those tools used without an external power source and include (*a*) measuring tools, (*b*) hand boring and drilling tools, (*c*) tightening tools, (*d*) striking tools, (*e*) gripping tools, (*f*) cutting tools, and (*g*) pouches and equipment bags.
3. Power tools are those tools that require an external source of energy such as electricity, hydraulics, or pneumatics.

4. Cable TV construction tools are special tools used for the installation, repair, or construction of a CATV plant.
5. Safety equipment is used to protect the CATV worker in the performance of the job and includes (*a*) warning signs, (*b*) traffic cones, (*c*) fire extinguishers, (*d*) first-aid kits, (*e*) safety goggles and shields, (*f*) hard hats, (*g*) traffic vests, (*h*) gloves, (*i*) manhole ventilators, and (*j*) safety fences.

REVIEW QUESTIONS

1. Name the two measuring tools covered in this chapter.
2. Describe a lineman's wrench.
3. Name the three types of hammers covered in this chapter.
4. Name the two cutting tools covered in this chapter.
5. What is the purpose of the lashing machine?
6. What is a strand hook?
7. Name three hand-held digging tools.
8. What is the purpose of a pulling grip?
9. What are cable blocks used for?
10. How long are the sections of lay-up sticks discussed in this chapter?
11. What is the purpose of a powered auger?
12. What is the function of a motor generator?
13. Name three safety "Do's" concerning the use of a knife.
14. Name five safety rules concerning ladders.
15. Name four safety rules concerning electricity.

10
CHAPTER
POLE CLIMBING

INTRODUCTION

In this chapter you will learn about:

1. Climbing equipment used by CATV technicians and care of this climbing equipment
2. Safety equipment that pole climbers use
3. The procedures for testing a wooden pole for possible electrical shock hazards and structural defects
4. The proper method of climbing a wooden pole
5. Safety rules for pole climbing

Because most of the cable construction at present is done utilizing poles, the CATV technician must have a thorough knowledge of climbing equipment as well as skill in its use. The proper understanding, use, and care of this equipment is essential, not only for quality work, but also for the safety of the lineman.

POLE-CLIMBING EQUIPMENT

The basic components of pole-climbing equipment are described in the following paragraphs.

Climbers

Climbers are J-shaped metal tools used to climb poles. Attached to each climber is a pointed *gaff* which is used to support the lineman while working aloft. Although there are two types of climbers, fixed and adjustable, only the adjustable is featured here. Figure 10–1 shows the right leg climber with straps and pads attached.

Adjustable climbers may contain either the short sleeve, which adjusts the climber to a maximum length of 19 in., or the longer sleeve, which adjusts to a maximum of 21 in. Sleeves are adjustable in ¼-in. increments. The various parts of a climber are shown in Fig. 10–2. Figures 10–3 and 10–4 show typical ankle straps and leg pads.

Straps and pads should be cleaned with warm water and saddle soap every 3 months. When dry, they should be treated with a coating of Neats-Foot Oil.

Climbers are fitted by adjusting the sleeve to within 1 in. of the bone that projects beneath the knee. When the correct length is found, fasten the sleeve to the leg iron with the screws provided.

Fig. 10-1. Pole-climbing climbers *(Klein Tools, Inc.).*

To attach the ankle strap assembly to the climbers (Fig. 10–5), use the following procedure:

1. Position the split ring so that the wear pad is pointed toward the front of the climber.

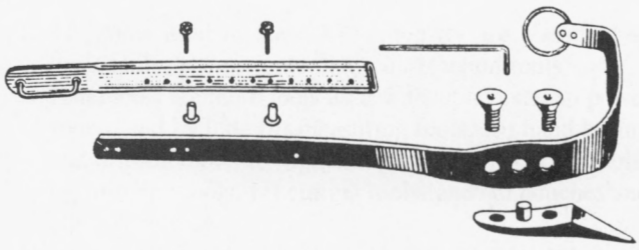


Fig. 10-2. Parts of the climber *(CWY Electronics).*

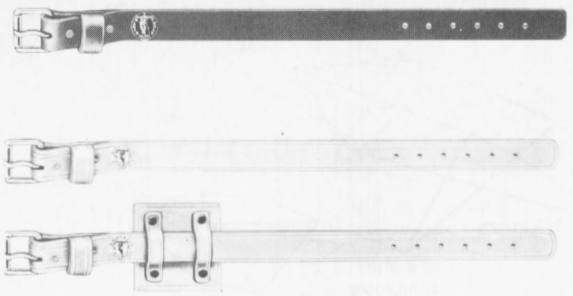


Fig. 10-3. Various styles of ankle straps *(Klein Tools, Inc.).*

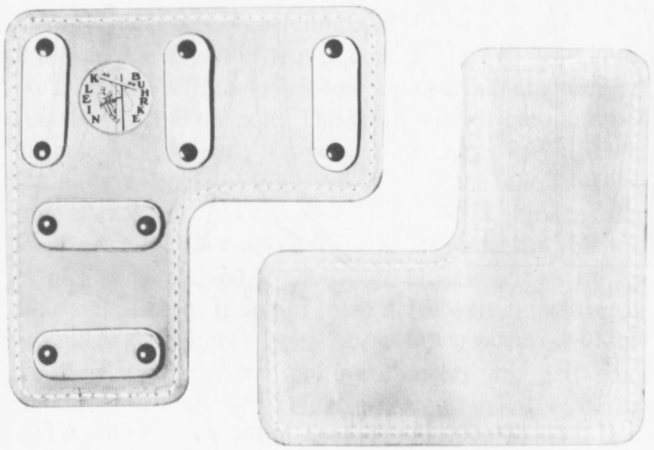


Fig. 10-4. Leg pads *(Klein Tools, Inc.).*

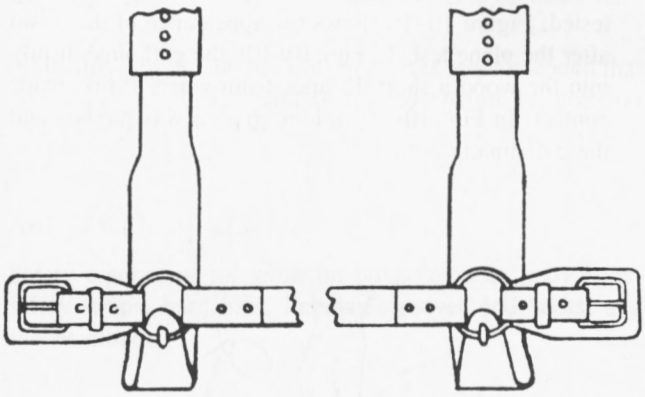


Fig. 10-5. Attachment of ankle straps *(Klein Tools, Inc.).*

Attach gaff with locator pin to leg iron middle hole. Thread screw into bottom hole (nearest gaff point). Do not seat screw. Thread shorter screw through flat portion of gaff. Alternate tightening of both screws until seated. Do not exceed 20 lb-ft torque on screw.

Fig. 10-6. Replacement gaffs *(CWY Electronics).*

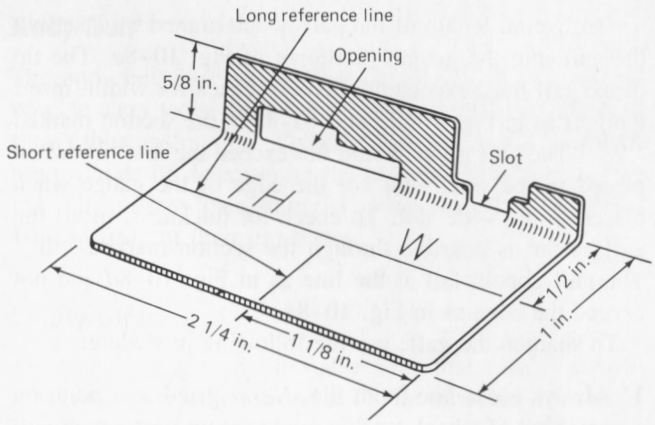


Fig. 10-7. Gaff gauge.

2. Open the split ring and thread onto the solid loop on the climber in the same manner as a regular key ring.

To attach the leg pads, thread the sleeve through the two loops provided and then thread the leg strap through the pad loop, the strap loop, and then the other pad loops. Remember to position the pad to have the pad cover the inside and front of each leg.

Since the gaff (Fig. 10–6) is the part of the climber that keeps the worker on the pole, it would be very foolish to neglect its care. To check the condition of the gaff, a gaff gauge (Fig. 10–7) is used. Figure 10–8 shows the proper method of using the gaff gauge.

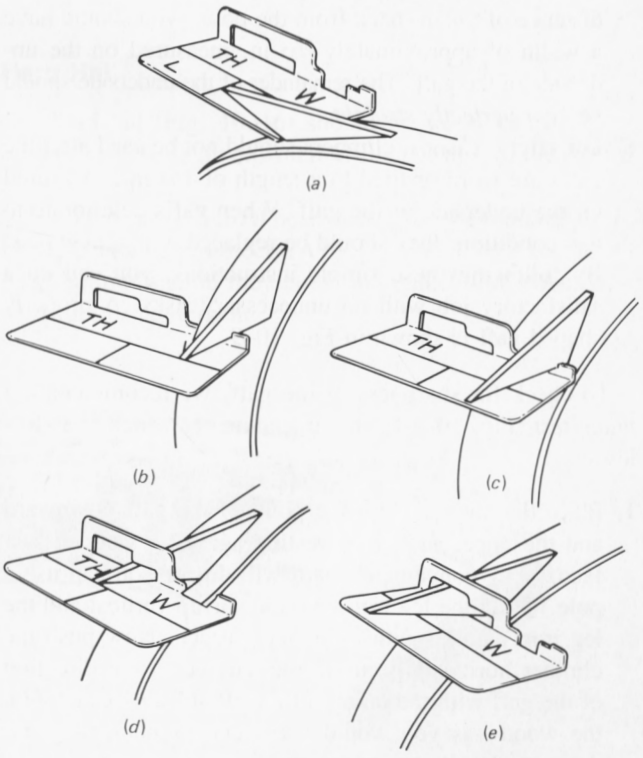


Fig. 10-8. Using the gaff gauge *(Klein Tools, Inc.).*

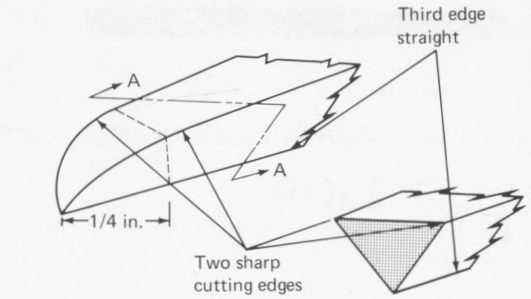
The overall length of the gaff is determined by inserting the gaff into the gauge, as shown in Fig. 10–8*a*. The tip of the gaff must exceed the line. To check for width, insert the gaff as in Fig. 10–8*b* and 10–8*c* in the section marked "W." The gaff point should not exceed the first line when placed in the small slot nor the edge of the gauge when placed in the wide slot. To check for thickness, insert the gaff as far as possible through the section marked "th." The gaff should fall at the line as in Fig. 10–8*d* and not exceed the edge as in Fig. 10–8*e*.

To sharpen the gaff, use the following procedure:

1. Always use a fine-tooth file. *Never* grind to a point on any kind of wheel, as this might set up heat which will spoil the temper of the gaff and make it dangerous to use.
2. Set the climber in a smooth jaw vice with the gaff uppermost and the stirrup of the climber turned up so that it can be filed from heel to point of the gaff. File toward the point and down to the edges of the underside of the gaff. Remove only sufficient material to make a good point. *Never* cross-file. Cross-filing marks tend to weaken the gaff when under load. Remove any file marks by honing.
3. *Do not* make a needle point. File both side slopes to even shaped surfaces. The top ridge of the gaff must be perfectly straight and *should not be touched* unless necessary. The final point is always in the top ridge of the gaff.
4. The underside of the gaff should be left perfectly straight (flat) to within ¼ in. of the point, then rounded slightly toward the top ridge of the gaff on a ¼-in. radius. At a distance of 1/16 in. back from the point, you should have a width of approximately 3/32 in. measured on the underside of the gaff. The remainder of the underside should be *kept perfectly straight*.
5. For safety reasons, climbers should not be used after the gaffs are worn or filed to a length of 1¼ in., measured on the underside of the gaff. When gaffs deteriorate to this condition, they should be replaced with a new pair. By following these simple instructions, you can do a satisfactory job with no unnecessary risks. A properly shaped gaff is shown in Fig. 10–9.

To check for sharpness of the gaff, we recommend the *plane test* (Fig. 10–10), the procedure for which is as follows:

1. Place the climber with the point of the gaff downward and the upper strap loop resting against a wooden surface. (Any convenient board will do, or you can use a pole.) Hold the leg iron with the stirrup vertical and the leg iron parallel with the wood surface. Now push the climber horizontally along the surface in the direction of the gaff with the point of the gaff still in contact with the wood—as you would a carpenter's plane. Use no downward pressure except the weight of the climber (see Fig. 10–10*a*).



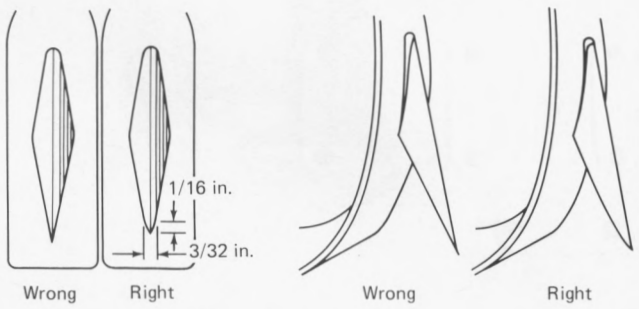


Fig. 10-9. Proper gaff shape.

2. If the gaff point buries itself in the wood within a few inches, the gaff may be considered *properly sharpened*. If the gaff point merely slips, slides, or plows a shallow groove in the wood, it is not properly sharpened and should not be used until resharpened and successfully tested. Figure 10–10 shows the appearance of the wood after the plane test. In Fig. 10–10*b* the gaff sinks firmly into the wood a short distance from where it first made contact. In Fig. 10–10*c* a long groove was plowed and the gaff finally cut out.

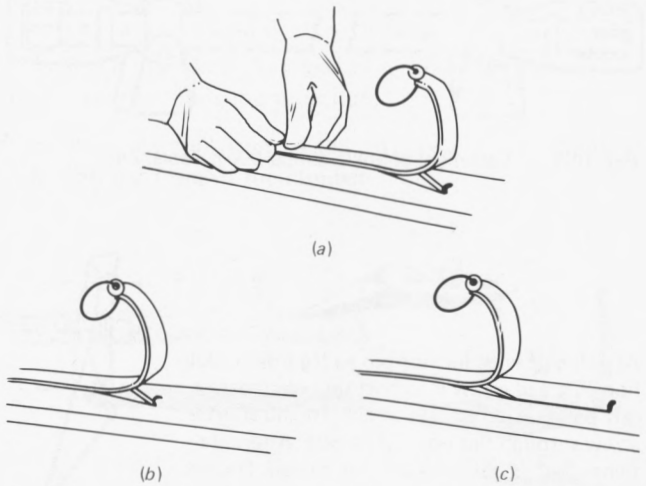


Fig. 10-10. Plane test, showing correct (*b*) and incorrect (*c*) sharpening *(Klein Tools, Inc.)*.

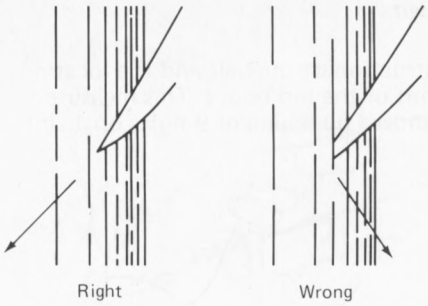


Fig. 10-11. Penetration of gaff *(Klein Tools, Inc.).*

The critical part of the climber is the point of the gaff—it is a cutting edge like that of a chisel. In Fig. 10–11, the sketch on the left illustrates how a properly sharpened gaff cuts its way into the pole. The sketch at the right illustrates the path an improperly sharpened or a dull gaff would take.

Climbers should be inspected daily for the following possible defects: (1) loose or cracked gaffs, (2) broken strap loops or rings, (3) cracked leg irons or sleeve, (4) blunted or nicked gaffs, and (5) loose or broken screws on the adjustable sleeve. If any of these defects are found, repair or replace the climber *immediately*.

When storing or transporting climbers, the gaff point should be protected by a gaff guard. A gaff guard is a device that slips over the gaff and protects it from dulling or injury. The gaff guard also protects the worker and the other climbing equipment from being cut by the gaff.

Climbers should never be worn for working on the ground, climbing ladders, or walking across streets or other hard surfaces.

WARNING In the interests of safety it is recommended that only the original gaff and two replacements be used on replaceable gaff climbers.

SAFETY EQUIPMENT

Safety equipment for work on poles includes body belts, safety straps, hard hats, lineman's gloves and boots, and rubber gloves.

Body Belt

The body belt is a wide belt used by workers who climb poles to carry tools, connectors, and hardware. Figure 10–12 shows the construction of a body belt. Figure 10–13 shows the methods of determining the proper size of belt for an individual. Most linemen prefer to have the D rings located 1 in. in front of their hip bones.

Safety Strap

The safety strap is an adjustable strap that varies between 5 ft 8 in. to 8 ft in length and is 1¾ in. in width. The safety strap snaps into specially designed metal rings on the body belt called "D rings." Figure 10–14 shows a typical safety strap. When in use, the buckle is on the outside as shown in Fig. 10–15 with the snaps pointing outward.

When the worker is either climbing or descending poles under normal conditions and the strap is not in use, *both* snaps should be engaged in the same D ring for purposes of safety. The snap on the double end should be positioned so that the *keeper* is pointed outward, and the keeper of the other snap should face inward.

Although nylon body belts and safety straps are available, most are made of leather.

The following conditions should be checked for prior to use of either the body belt or the safety strap: (1) cracks, cuts, or nicks; (2) deteriorated stitching; (3) loose rivets; (4) a defective buckle; and (5) poor action of the snaps on the safety strap. The same procedures should be used to clean and oil leather body belts and safety straps as was outlined for care of the straps and pads on the climber.

Hard Hat

The hard hat (Fig. 10–16) should be worn whenever the worker is close to a construction site because of the danger of falling objects.

Hard hats are *required* headwear when the worker climbs because they help protect CATV personnel from accidental head injuries should they come in contact with either pole hardware or equipment.

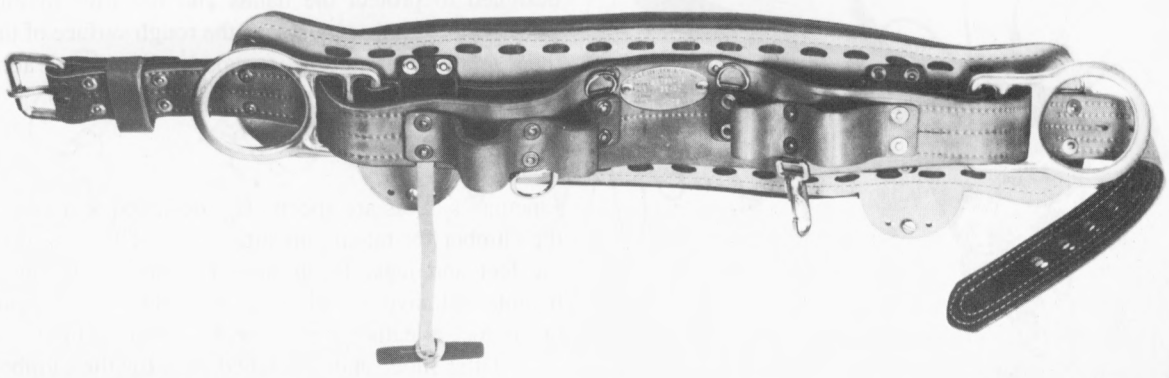


Fig. 10-12. Body belt *(Klein Tools, Inc.).*

Two ways to properly size a lineman's body belt

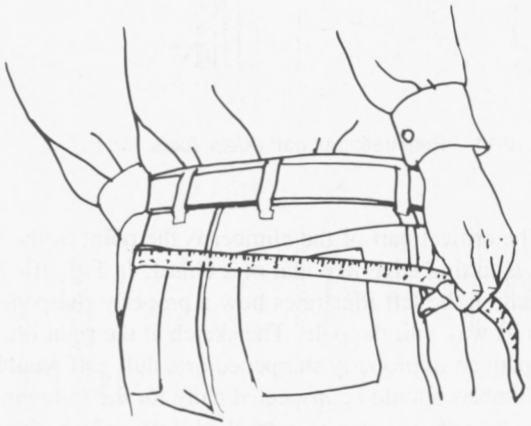
The degree of comfort a lineman obtains from a body belt depends on the construction of the belt and the location of the D rings. Most lineman prefer to have the D rings located about 1 in. in front of the hip bones. This measurement can be obtained in two ways as explained below. Klein belt billets have standard punching of 9 holes on 1-in. centers to provide proper fit in relation to D-ring measurements.

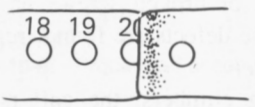
1. How to size a body belt using a tape measure

To obtain the correct D-to-D size with a tape measure, measure from hipbone to hipbone across the back as shown in the illustration, and add 2 in. This is the D-to-D size.

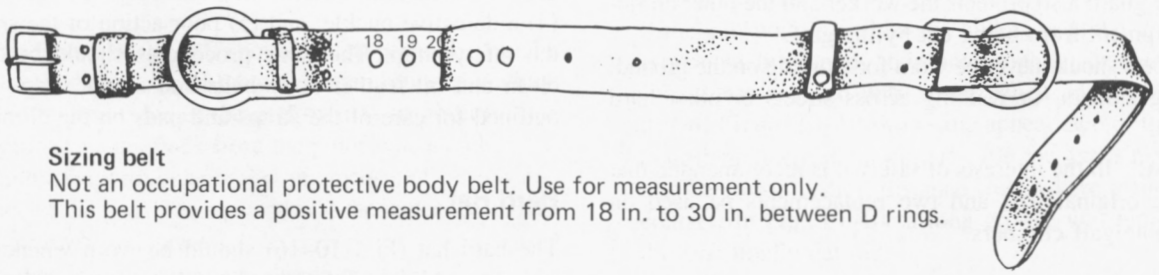
2. How to size a belt using a Klein Sizing Belt

1. Unbuckle and unsnap the belt so that there are two separate parts.
2. Hold D rings in desired position on hips and snap buttons to the nearest stud.
3. Now buckle the belt on. If D rings fit where desired, the proper D-to-D size will be visible to the left of the snaps. (NOTE: disregard location of the buckle—correct length buckle end will be furnished).





Adjusted for size.
D-to-D size.



Sizing belt
Not an occupational protective body belt. Use for measurement only.
This belt provides a positive measurement from 18 in. to 30 in. between D rings.

Fig. 10-13. Proper method of determining belt size *(Toner Cable Equipment, Inc.).*

Fig. 10-14. Climber's safety strap *(Klein Tools, Inc.).*

Lineman's Gloves

Lineman's gloves are constructed of heavy leather and are designed to protect the hands and forearms of climbers. Because the climber must grip the rough surface of the pole, there is always danger from wood splinters and abrasions. Figure 10–17 shows a pair of lineman's gloves.

Lineman's Boots

Lineman's boots are specifically designed to accommodate the climber for maximum support as well as protection for the feet and legs. Boots are available in 10- and 16-in. heights and have a steel arch, steel kick plate affixed to the inside toe, a leather flap to prevent wear on the inside portion of the shoe, and a notched heel for the climber to fit into. Figure 10–18 shows lineman's boots.

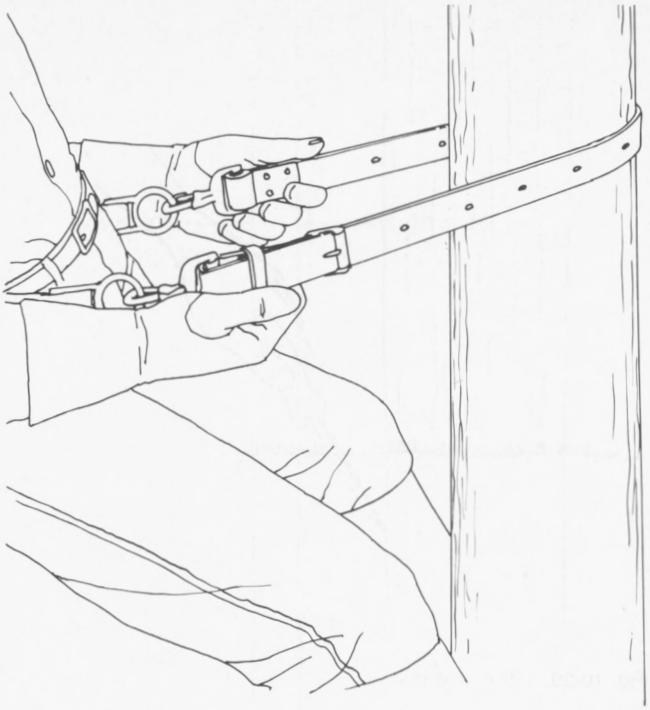


Fig. 10-15. Position of safety strap when in use.

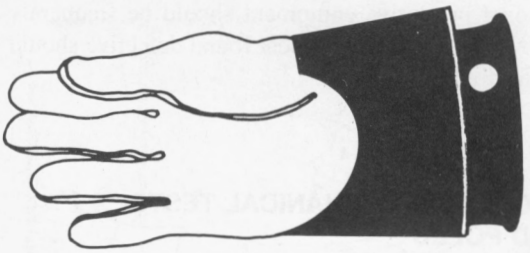


Fig. 10-17. Lineman's gloves *(M/A Com Comm-Scope).*

Fig. 10-18. Lineman's boots *(M/A Com Comm-Scope).*

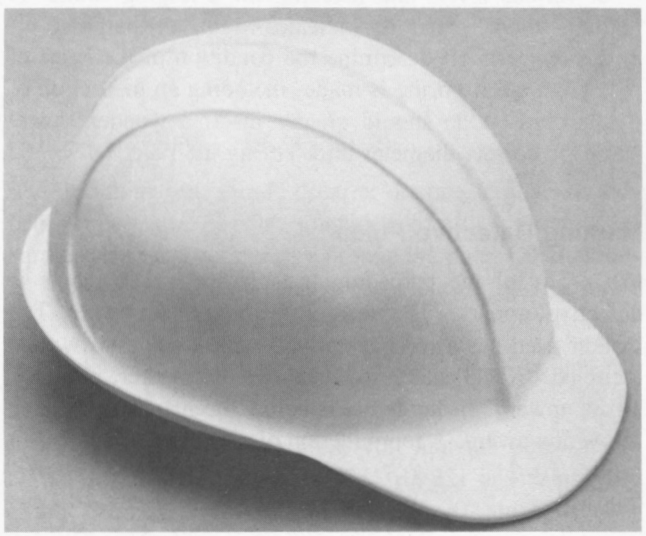


Fig. 10-16. Lineman's hard hat *(Klein Tools, Inc.).*

Rubber Gloves

Personnel intending to work around live conductors should don rubber gloves and should not remove the gloves until entirely clear of them. Rubber gloves should not be used for any purpose except when working around electrical hazards.

Leather protectors should always be worn over rubber gloves and should not be used for any purpose other than to protect the rubber gloves from damage. Rubber gloves should be checked before each use. Figure 10–19 shows one method of air-testing rubber gloves.

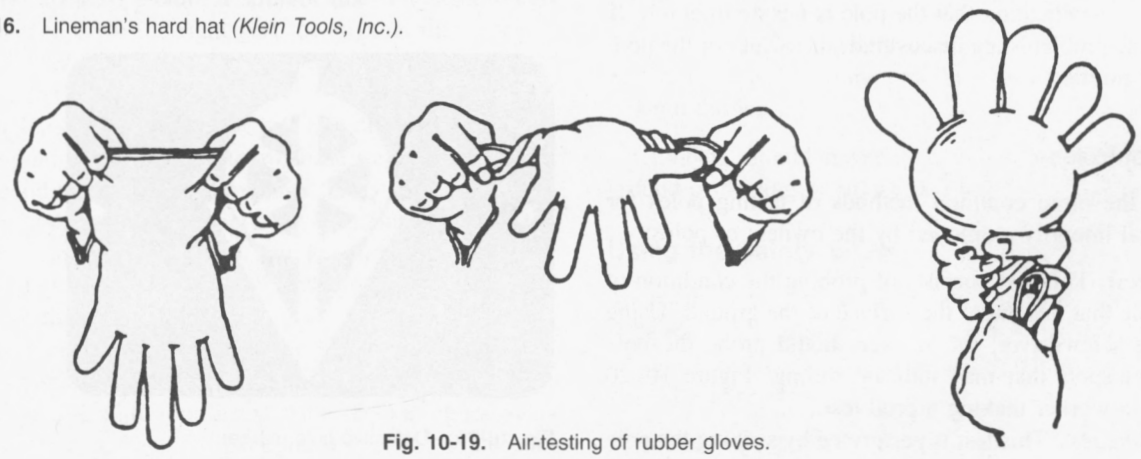


Fig. 10-19. Air-testing of rubber gloves.

All personal protective equipment should be frequently inspected by the wearer. Equipment found defective should be either repaired or replaced.

ELECTRICAL AND MECHANICAL TESTS ON WOOD POLES

Before considering climbing or working on a pole, one should be convinced that the pole is secure and will support the weight of the climber. In addition, poles should be tested for voltage if there is any suspicion of a difference of potential between the pole and the earth ground.

Electrical Testing of Poles

Some situations that would warrant a voltage test on a pole are (1) a broken ground wire; (2) a power line touching the pole; or (3) a warning issued by the power company, telephone company, or a supervisor regarding the presence of a possible hazard.

The voltage test is performed by use of a tester especially designed for the purpose. An energized pole should never be climbed. Notify your supervisor whenever a suspected "hot" pole is found.

Mechanical Testing of Poles

Procedures for inspecting and testing poles before climbing are described in the following paragraphs and should be performed to minimize pole-related accidents during climbing or working aloft. Procedures for marking defective poles are also given.

Visual Inspection

Before climbing a pole, one should perform a visual inspection to rule out the following defects and conditions: (1) cracks or splits in the pole; (2) termites or other insects; (3) excessive wear from being climbed; (4) evidence of rotting; (5) the presence of a defective pole marker; and (6) any condition indicating that the pole is unsafe to climb. If any of these problems are discovered, the owner of the pole should be notified.

Testing of Poles

Some of the more common methods of testing poles for mechanical integrity employed by the owners of poles:

1. *Prod test*. This test consists of probing the condition of the pole that lies under the surface of the ground. Using a long screwdriver, the worker should probe the pole for soft spots that may indicate rotting. Figure 10–20 shows a worker making a prod test.
2. *Sounding test*. This test is performed by striking the pole at various levels and listening for a ringing sound. A dull "thud" generally indicates rotting of the pole.
3. *Boring test*. To determine the condition of the heart of a pole, a test boring is made, including an inspection of the chips. One should *always* insert a wooden dowel of the correct diameter after boring the pole.

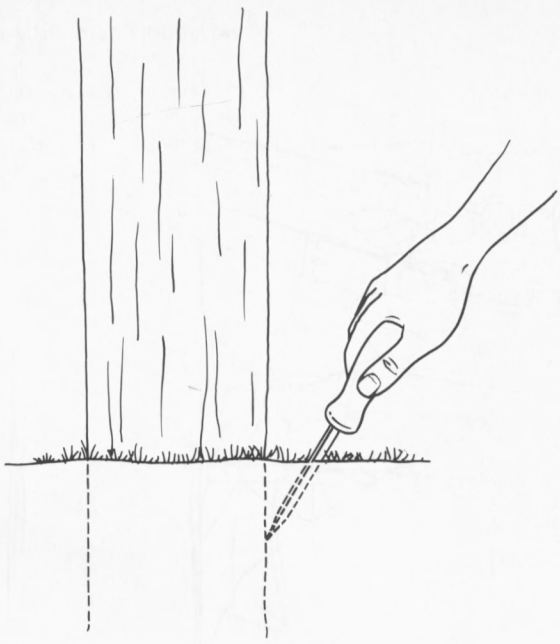


Fig. 10-20. Pike-pole test.

Marking Defective Poles

When any of the preceding tests indicate that a pole is defective, a marker is placed on the pole by its owner. The marker used has a red background with a white arrow and a circled "X." If the defect is above the marker, point the arrow upward. If the defect is below the marker, point the arrow downward. A reproduction of a pole marker is shown in Fig. 10–21.

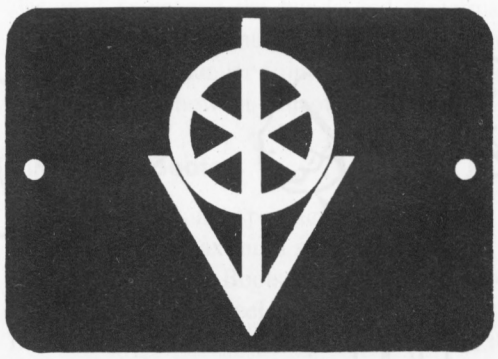


Fig. 10-21. Defective pole marker.

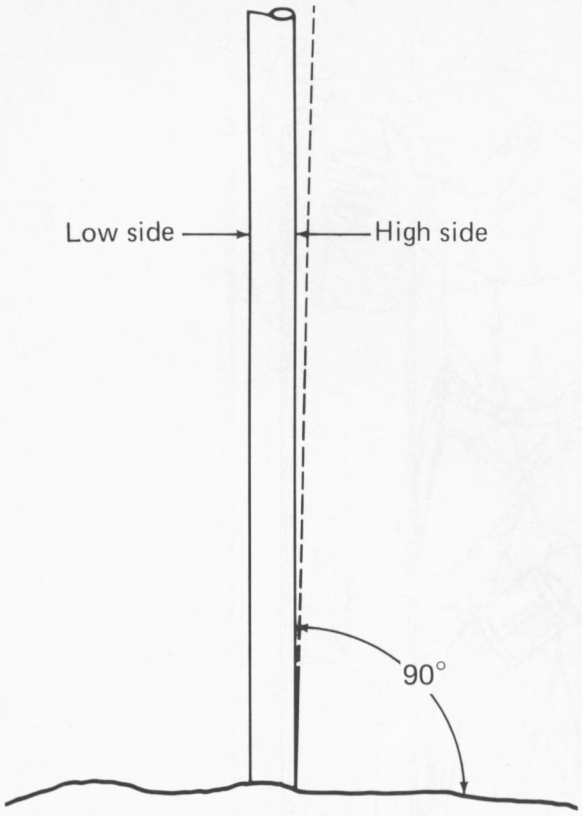


Fig. 10-22. Determining the high side of a pole.

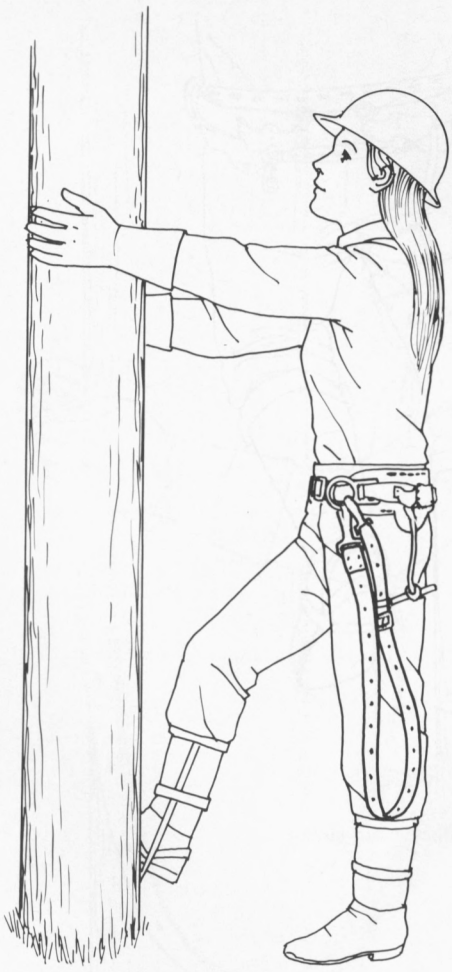


Fig. 10-23. Starting the climb.

POLE-CLIMBING TECHNIQUES

The first thing you should do after donning climbers, body belt, safety strap, boots, long-sleeved shirt, gloves, and hard hat is to inspect the area around the pole. Obstructions to good footing such as stones and pieces of wood should be removed and holes avoided.

CAUTION Do not attempt to climb a pole in the absence of a qualified instructor.

If, after inspecting the area, you find the pole safe to climb, locate the high side (Fig. 10–22) and prepare to climb. Starting with the right foot at a 30° angle with the pole (Fig. 10–23), picture a straight line running through its center and drive the right gaff toward that line. As you move your left hand up the pole, step up on the right gaff and drive the left gaff into the pole. Moving the right hand up the pole, step up on the left gaff and drive the right gaff into the pole again. Repetition of these steps will result in your ascending the pole. Remember that at all times while climbing, a three-point contact must be maintained with the pole: one arm and both legs or one leg and both arms. The average step varies between 10 and 14 in. depending on the size of the lineman.

When ascending a pole you should keep your back straight and arms and legs relaxed. Remember, climb with your legs, don't pull with your arms. An effective leg stroke is one that causes the gaff to penetrate the pole without any side thrusting. To remove the gaff, your foot should be twisted, with your toe used as a fulcrum. When you descend, the gaff will pull away as your knee is swung away from the pole. Figure 10–24 shows an effective leg stroke, and Fig. 10–25 shows the proper climbing posture.

To descend, perform the following steps as shown in Fig. 10–26:

1. Lower the hand opposite the leg to be lowered.
2. Straighten the leg.
3. Aim this leg at the center of the pole.
4. Drive the gaff into the pole by dropping all your weight onto the leg.

Climbers should never be worn while working on the ground or driving or riding in a vehicle.

Using the Safety Strap

To place the safety strap around the pole, the following steps should be followed. We will assume that the worker is right-handed; therefore, the safety strap will be on the worker's left side.

1. Make sure that both feet are properly gaffed in.

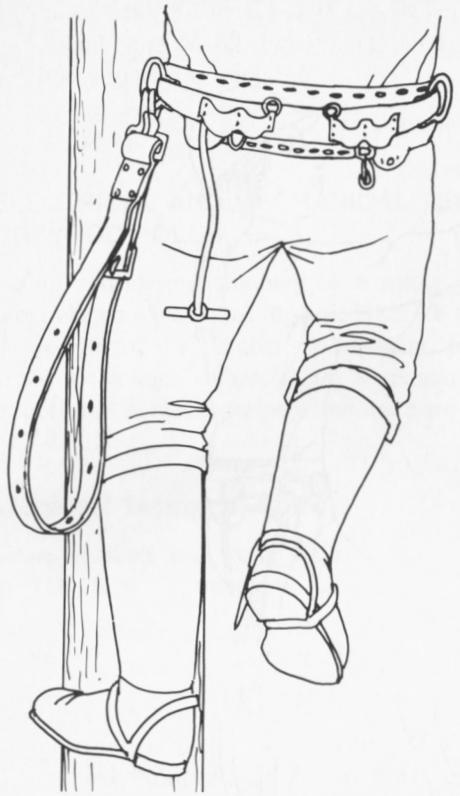


Fig. 10-24. The effective leg stroke.

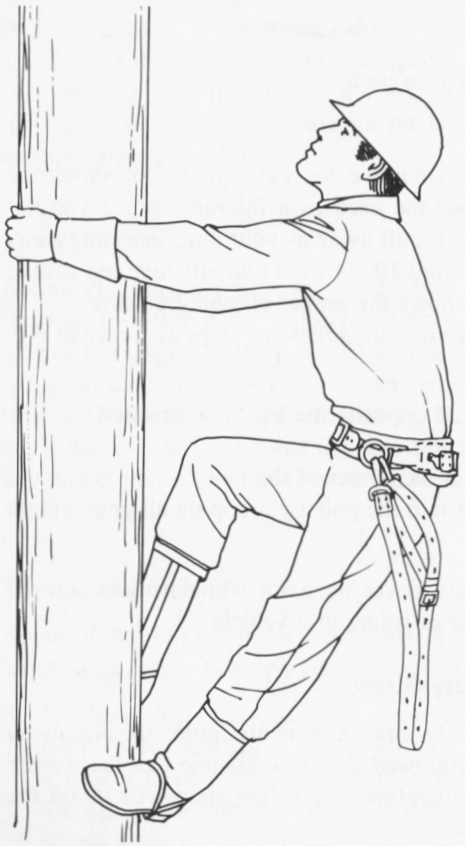


Fig. 10-25. Continuing the climb.

Fig. 10-26. Descending the pole.

2. To facilitate movement, one foot should be 8 to 10 in. *above* the level of the other.
3. While holding the pole with the right hand, reach down with the left and unsnap the safety strap. (see Fig. 10–27).
4. Pass the unsnapped end of the safety strap to the right hand as shown in Fig. 10–28.
5. Grasp the pole with your left hand, and snap the safety strap into the D ring on the right side of the body belt.
6. Make a visual inspection to ensure that both snaps are properly engaged into their respective D rings.
7. With your free hand, move the strap up the pole to a position slightly higher than the body belt.
8. Lean back and start working.

The proper position of the safety strap was shown in Fig. 10–15. When it becomes necessary to move about on the pole, the strap should be moved as shown in Fig. 10–29. By gripping the pole with one hand and pulling, the strap can be moved up or down the pole with the other hand.

When used, the snaps on the safety strap should face outward and there should not be any twists in the strap.

Practice Climbing

Practice climbing should be done at the base of a pole until the proper climbing techniques are mastered. To begin

Fig. 10-27. Releasing the safety strap.

place your feet on the ground at about a 90° angle with each foot against the sides of the pole. Extend both of your arms straight out from your shoulders and hold onto the back of the pole with your hands. As shown in Fig. 10–30, place your hips back from the pole and keep your body in a vertical position. While in this position, the climber should practice leg strokes and safety strap belting-in procedures.

NOTE New workers should practice at the foot of the pole until the proper technique is achieved. Before ascending a pole, the worker should be proficient in the proper positions of hands, body, and feet.

SAFETY WHILE CLIMBING

The following rules should be observed while climbing or serving as a ground helper for a climber:

1. Inspect all of your equipment daily for defects and flaws that might result in injury or death.
2. No one should be at the foot of a pole while a worker is climbing or working on it.
3. All persons should wear hard hats while in the vicinity of cable construction.

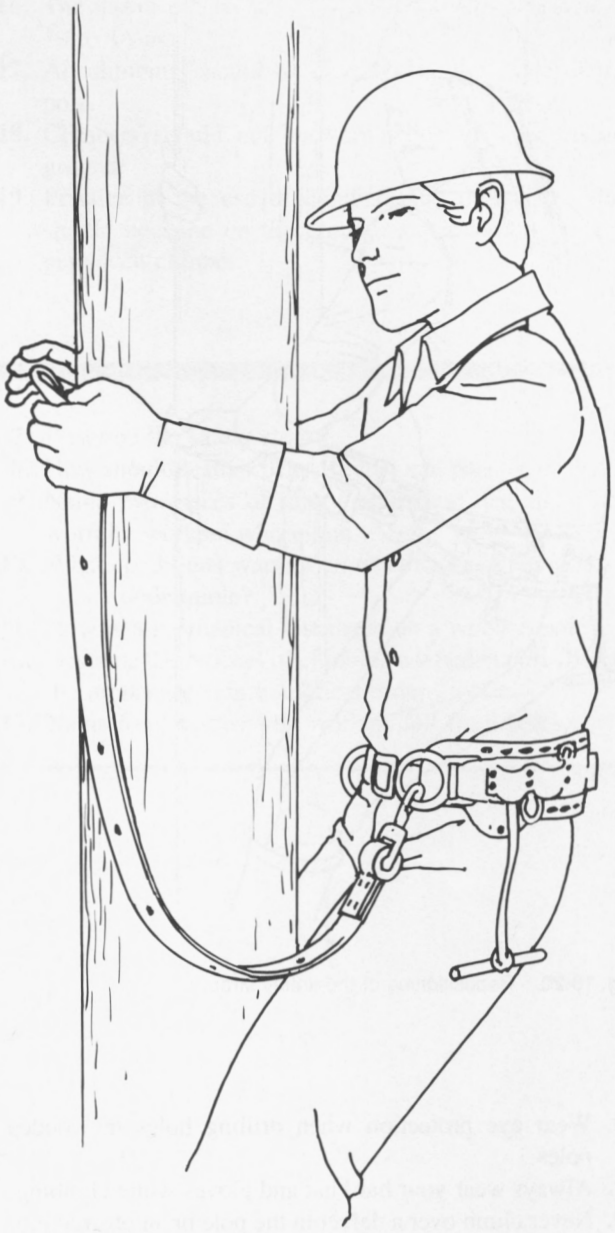


Fig. 10-28. Passing the safety strap to the right hand.

4. No more than one climber should be on a pole. When conditions necessitate, two climbers may be on the same pole provided (*a*) the first climber climbs to the working location and belts in before the second climber starts; (*b*) the second climber climbs the opposite side of the pole; and (*c*) during descent, one climber remains belted in until the other is down and out of the way.
5. Never wear climbers while on a pole equipped with steps.
6. When working, consider all wires to be energized.
7. Avoid climbing an ice-covered or slippery pole, but, if absolutely necessary, climb on the most slippery side, thereby leaving the better side for the hands.

Fig. 10-29. Repositioning of the safety strap.

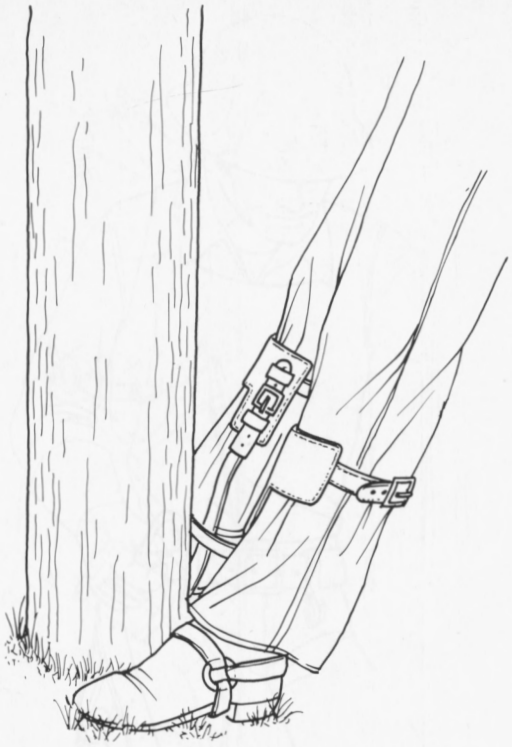


Fig. 10-30. Practice position.

8. Wear eye protection when drilling holes in wooden poles.
9. Always wear your hard hat and gloves while climbing.
10. Never climb over a defect in the pole or an obstruction. It is better to rotate 90° and continue the climb.

Some of the more common reasons workers fall from poles are the following:

1. Carelessness in climbing techniques
2. Improper climbing procedures
3. Defective equipment
4. Broken gaffs
5. Worn gloves
6. Horse play
7. Attempting to climb a slippery pole
8. Being tired or faint
9. Missing a step on a pole equipped with steps
10 Gaffing into a nail or knot
11. Climbing a defective pole
12. Losing their balance by not having three point contact.

SUMMARY

1. The proper understanding, use, and care of climbing equipment are essential for working skillfully and safely.
2. Climbers are J-shaped metal tools that are used to climb poles.
3. To check the condition of the gaff, a gaff gauge is used.
4. One of the best ways to determine the sharpness of a gaff is to perform a plane test.
5. Whenever climbers are transported or stored, the gaff should be protected by gaff guards.
6. The body belt is a wide belt worn around the worker's waist. Its function is to secure the safety strap and to hold tools.
7. The safety strap is used to secure the worker to the pole while working.
8. A hard hat should be worn for climbing or work in the construction area.
9. Lineman's gloves are used to protect the hands and forearms of the worker from injury while climbing.
10. Lineman's boots are especially designed footwear to protect and support the feet and legs of workers who climb.
11. Rubber gloves are to be worn whenever cable personnel are working near current-carrying conductors.

12. Whenever a wooden pole is suspected of being energized, it should be tested for a potential difference between it and ground.
13. Whenever a wooden pole is suspected of having a structural defect, it should undergo mechanical testing.
14. Whenever a pole is found to be structurally defective, a defective pole marker should be affixed.
15. Before climbing, the worker should inspect the area around the pole for obstructions to good footing.
16. The distance between steps during ascent of a pole is 10 to 14 in.
17. All climbing should be done on the high side of the pole.
18. Climbers should not be worn while working on the ground.
19. Practice in the use of climbers and the safety strap should be done on the ground, supervised by an experienced climber.

REVIEW QUESTIONS

1. What is the name of the pointed part of the climber that penetrates the pole?
2. Name two of the three dimensions of a gaff that the gaff gauge measures.
3. How many times may the gaffs be replaced before a pair of climbers should be discarded?
4. Describe the procedure for sharpening gaffs.
5. When climbers are stored, what precaution was recommended?
6. Describe the body belt.
7. Describe the safety strap.
8. How should leather belts, straps, and pads be cleaned?
9. Name two pieces of safety equipment that should be worn by workers who climb.
10. What conditions warrant an electrical test being made on a wooden pole?
11. How is a mechanical test made on a wooden pole?
12. Describe the process of climbing a wooden pole, listing the proper steps in numerical order.
13. Name five reasons why workers fall from poles.

11 CHAPTER

CONSTRUCTION HARDWARE AND POLE INSTALLATION PROCEDURES

INTRODUCTION

In this chapter you will learn about:

1. Woodworking and metalworking fasteners
2. The hardware used in aerial construction
3. The setting, facing, guying, and anchoring of wooden poles

Aerial construction is concerned with the portion of the cable distribution system that is suspended on poles. Most CATV systems utilize aerial construction because it is the least expensive to build and the easiest to maintain.

Construction and maintenance of a cable system require the combined knowledge and talents of both construction crews and service technicians.

FASTENERS FOR WOOD

Nails

Nails achieve their fastening or holding power when they displace wood fibers from their original positions. The pressure exerted against the nail by these fibers as they try to spring back to their original positions provides the holding power.

The usual type of shank is round, but there are various special-purpose nails with other types of shanks. The lengths of the most commonly used nails are designated by the *penny* system. The abbreviation for the word *penny* is the letter "d." Thus the expression "2 d nail" refers to a two-penny nail. The penny sizes and corresponding lengths of common nails are shown in Table 11–1.

Nails larger than 20 d are called *spikes* and are generally designated by their length in inches. Nails smaller than 2 d are designated in fractions of an inch instead of in the penny system and are termed *brads*.

Figure 11–1 shows the more common types of wire nails. The brad and the finish nail both have a deep countersink head that is designed to be "set" below the surface of the work.

Wood Screws

Wood screws have several advantages over nails. They can hold the wood more securely, can be easily tightened, and generally are neater in appearance. They also may be withdrawn at any time without injury to the material. Wood screws are designated by material, type of head, and size. Various types of wood screw heads are shown in Fig. 11–2.

The size of an ordinary wood screw is indicated by the length and body diameter (unthreaded part) of the screw.

TABLE 11–1. Common Nail Sizes

Size	2 d	3 d	4 d	5 d	6 d	7 d	8 d	9 d	10 d	12 d	16 d	20 d	30 d	40 d	50 d	60 d
Length	1	1	1	1	2	2	2	2	3	3	3	4	4	5	5	6

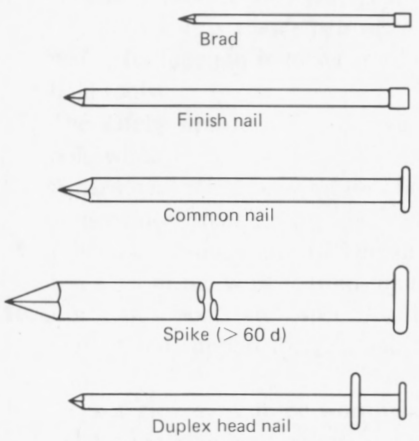


Fig. 11-1. Nail varieties.

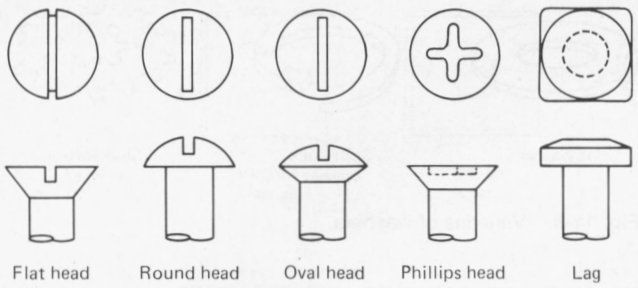


Fig. 11-2. Wood-screw heads.

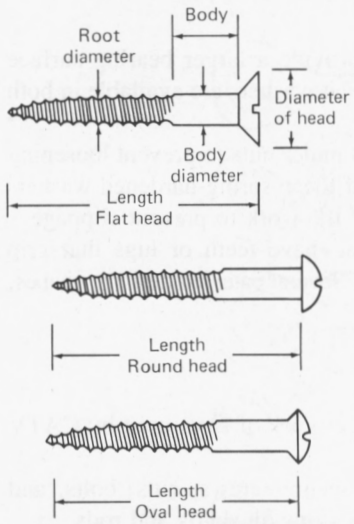


Fig. 11-3. Types of wood screws.

Figure 11–3 shows the three most common types of wood screws. Notice that the length is always measured from the point to the greatest diameter of the head.

Body diameters are designated by gauge numbers, running from 0 (for about a 1/16-in. diameter) to 24 (for about a 3/8-in. diameter). A designation of 1¼ - 9 means a No. 9 screw 1¼ in. long.

As a general rule, the length of a screw for holding two pieces of wood together should be such that the body of the screw simply passes through a hole in the top piece and the threads take hold in the bottom piece as shown in Fig. 11–4.

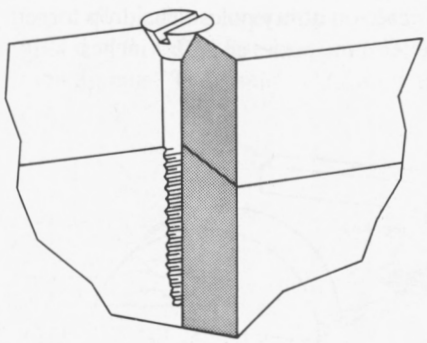


Fig. 11-4. Correct position of wood screw for securing two pieces of wood.

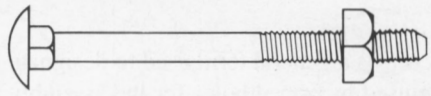


Fig. 11-5. Carriage bolt *(Anixter Bros., Inc.)*.

Bolts Used to Fasten Wood

A bolt used to fasten wood, instead of threading into the wood, passes through drilled holes and is held by a nut. Figure 11–5 shows a carriage bolt, the most common bolt used for fastening wood.

FASTENERS FOR METAL

Bolts Used to Fasten Metal

When installing bolts, always be certain to install them with the head up. This way, if the nut has been improperly tightened or is shaken loose by vibration and falls off, the bolt will remain in its hole and continue to provide some holding capability.

Be certain that the grip length of the bolt is correct. The grip length is the length of the unthreaded portion of the bolt shank. Generally the grip length should equal the thickness of the material that is being bolted together. Not more than *one* thread should bear on the material, and the threaded portion of the shank should be showing through the nut. The correct bolt grip length is shown in Fig. 11–6.

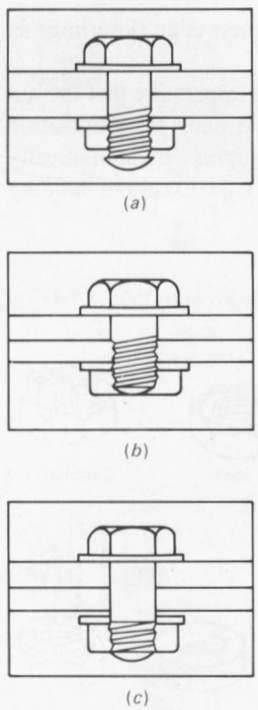


Fig. 11-6. Correct and incorrect grip lengths: bolt grip length correct (*a*); too short (*b*); too long (*c*).

Machine Screws

The term *machine screw* is a general term used to designate small screws that are used in tapped holes for the assembly of metal parts. Machine screws are manufactured in a variety of lengths, diameters, pitches (threads per inch), materials, head shapes, finishes, and thread fits.

Capscrews

Capscrews perform the same functions as machine screws, but are manufactured in larger sizes for heavier work. Sizes range up to 1 in. in diameter and 6 in. in length. Capscrews are sometimes referred to as *tap bolts*.

Nuts

Figure 11–7 shows some of the nuts used on metal fasteners. The most commonly used nuts are the square- and hexagon-shaped (Hex) nuts. In addition, there are also special nuts such as:

- *Jam nuts*—used above a standard hexagon nut to lock it in position. It is about half as thick as the standard hexagon nut and has a washer face.
- *Castellated nuts*—slotted so that a cotter key (covered later) may be pushed through the slots and into a matching hole in the bolt. This provides a method for preventing the nut from working loose.
- *Wing nuts*—used when a certain degree of tightness is needed. Wing nuts are turned by the thumb and the index finger.
- *Cap nuts*—used where appearance is an important consideration. They are usually made of chromium-plated brass.
- *Thumb nuts*—have cross cuts on their edge (knurling) so that they can be turned by hand.
- *Elastic stop nuts*—used where it is imperative that the nut not come loose. These nuts have a fiber or composition washer built into them which is compressed automatically against the screw threads to provide excellent holding power.

Fig. 11-7. Common types of nuts.

Fig. 11-8. Varieties of washers.

Washers

Figure 11–8 shows the types of washers used extensively in CATV work:

- *Flat washers*—used to provide a larger bearing surface for bolt heads and nuts. Flat washers are available in both round and square shapes.
- *Split-lock washers*—used under nuts to prevent loosening by vibration. The ends of these spring-hardened washers dig into both the nut and the work to prevent slippage.
- *Shakeproof lock washers*—have teeth or lugs that grip both the work and the nut. Several patented designs, shapes, and sizes are obtainable.

Keys

Figure 11–9 shows the three types of keys used by CATV workers.

Cotter keys are used to secure screws, nuts, bolts, and pins. They are also used as stops on shafts and rods.

Square and woodruff keys are used to prevent hand wheels, gears, cams, and pulleys from turning on a shaft. These keys are strong enough to carry heavy loads if they are fitted and seated properly.

AERIAL HARDWARE AND CONSTRUCTION DEVICES

Figure 11–10 shows a variety of the hardware items used in CATV aerial construction.

Some of the more common devices used in constructing a CATV system are:

- *Crossover clamps*—used to clamp strand cables together where they cross at right angles. Strand cables are used to hold the coaxial cable on utility poles. The drop forged clamp sections are 1½ in. wide and 3¼ inches long.

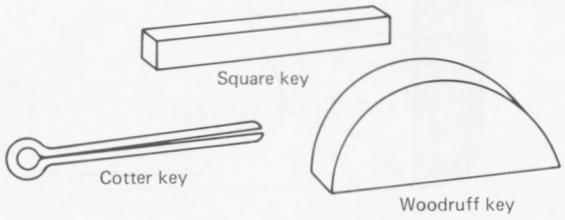


Fig. 11-9. Varieties of keys.

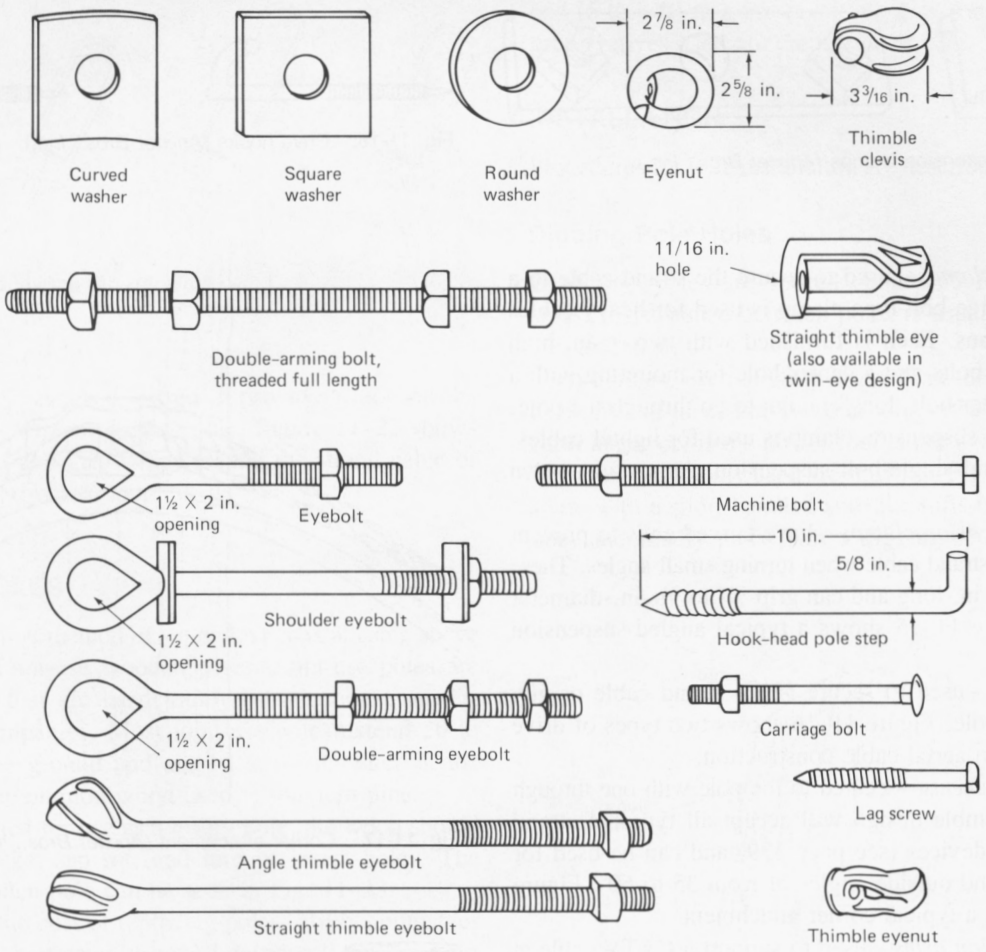


Fig. 11-10. Aerial plant hardware.

Lighter-weight formed clamps are also available. Figure 11–11 shows both types of crossover clamps used in aerial construction.

- *Guy clamps*—rolled from structural steel with straight parallel grooves that will not damage guy wire. Guy clamps are used to secure a guy wire to an anchor (covered later) or to a thimble eye bolt (Fig. 11–10). Guy wires are used to support utility poles. Figure 11–12 shows a two bolt guy clamp.
- *Lashing clamps*—are used to secure the lashing wire during cable lashing operations. Lashing clamps are furnished with a double-ended stud bolt, washers, and free-running nuts. Two styles of lashing clamps are shown in Fig. 11–13.

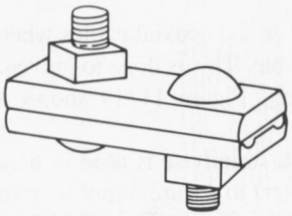


Fig. 11-12. Guy-wire clamp *(Anixter Bros., Inc.).*

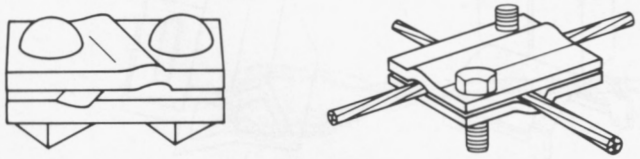


Fig. 11-11. Crossover clamps *(Anixter Bros., Inc.).*

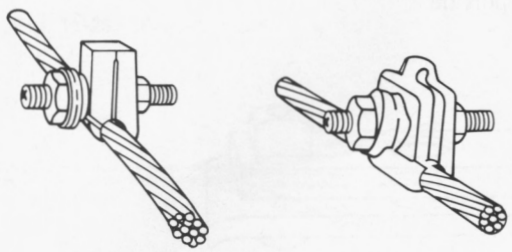


Fig. 11-13. Lashing clamps *(Anixter Bros., Inc.).*

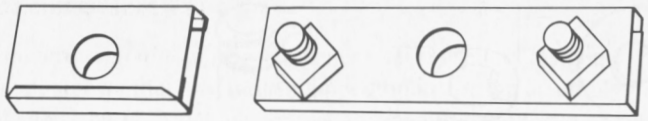


Fig. 11-14. Suspension clamps *(Anixter Bros., Inc.).*

- *Suspension clamps*—used to secure the strand cable to a pole. The three-bolt-type clamp is used for heavy cables and long spans. Each is furnished with two ½-in.-high carbon steel bolts and a center hole for mounting with a ⅝-in. diameter bolt, long enough to go through the pole. The one-bolt suspension clamp is used for lighter cables. Three-bolt and single-bolt suspension clamps are shown in Fig. 11–14.
- *Angled-suspension clamps*—have curved ends to prevent injury to the strand cable when turning small angles. These clamps are 7 in. long and can grip ¼- to 7/16-in.-diameter strand. Figure 11–15 shows a typical angled-suspension clamp.
- *Drive hooks*—used to secure either strand cable or guy wire to the pole. Figure 11–16 shows two types of drive hooks used in aerial cable construction.
- *Corner attachments*—secured to the pole with one through bolt. The thimble design will accept all types of strand dead-ending devices (see page 139) and can be used for both inside and outside angles of from 35 to 60°. Figure 11–17 shows a typical corner attachment.
- *Cable extension arms*—used to support a CATV cable at a distance from the pole. The extension arm shown in Fig. 11–18 is used where code requirements will not allow other cables to be moved to provide space for an additional cable.
- *Cable spacers*—used to separate the coaxial cables when they are lashed to the strand cable. This is done to prevent individual cables from chafing. Figure 11–19 shows a variety of cable spacers.
- *Strandvises and strandlinks*—a strandvise is used in pole guying operations (covered later) to secure a guy wire to either a pole or an anchor. Strandlinks are used to join two sections of guy wire together. Figure 11–20 shows a strandlink and three types of strandvises used in aerial construction.
- *Aerial support ties*—used to attach CATV coaxial cable to the strand cable and also to keep equipment cables clear of pole hardware. Figure 11–21 shows a typical aerial support tie.

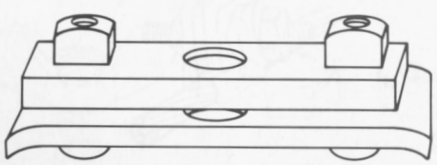


Fig. 11-15. Angled suspension clamp *(Anixter Bros., Inc.).*

Fig. 11-16. Drive hooks *(Anixter Bros., Inc.).*

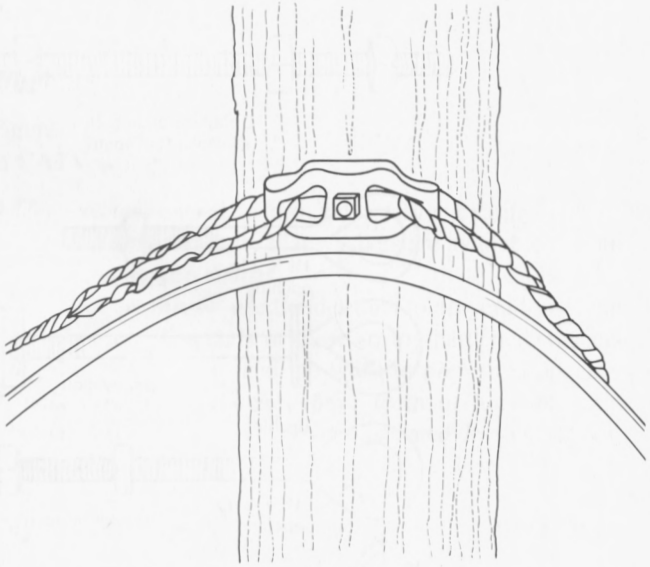


Fig. 11-17. Corner attachment *(Anixter Bros., Inc.).*

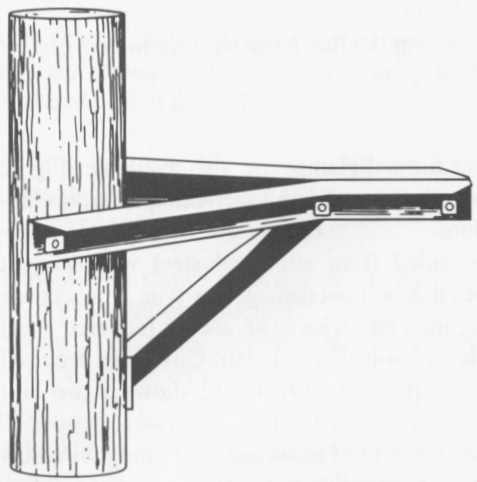


Fig. 11-18. Cable extension arm *(Anixter Bros., Inc.).*

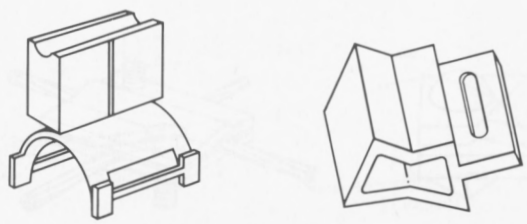


Fig. 11-19. Cable spacers *(Anixter Bros., Inc.).*

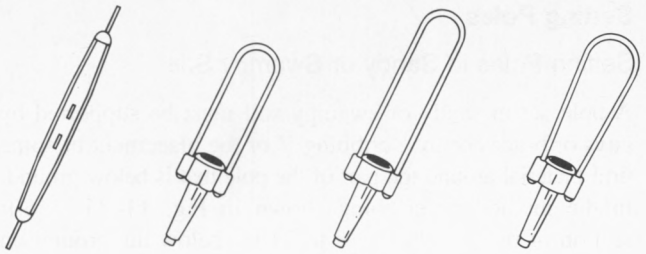


Fig. 11-20. Strandvises *(Anixter Bros., Inc.).*

- *A dead-end or guy grip*—used to provide a loop on the end of a guy wire or strand cable. Figure 11–22 shows how the dead-end grip wraps around the strand cable or guy wire to provide a loop.

WOODEN POLES

The most common method of supporting coaxial cable above ground is on joint-use wooden poles. Joint-use poles are wooden poles that are used jointly by telephone, power, and CATV companies. Most joint-use poles extend 20 to 50 ft above the ground and are 12 to 18 in. thick at the butt. The most common wood used is southern pine.

To be accepted for use as a utility pole, the wood should be free of cracks, sap rot, and bird or insect holes. The parts of a wooden pole can be seen in Fig. 11–23.

Because of the cost of replacing poles, utility companies purchase poles pretreated to retard deterioration. The most common method of treating poles is by submerging the butt end (6 to 8 ft) in a preservative for 1 to 4 h. The common preservatives used are creosote and pentachlorophenol.

INSTALLATION

Procedures for pole installation are described in this section.

Digging Pole Holes

Generally, poles are spaced about 150 ft apart. In rural areas, the distance between poles is usually lengthened to 200 to 250 ft.

Pole holes, each slightly larger than the butt of the pole to be placed in it, may be dug with either a power-driven earth auger or, if the power tool is not available, by hand. The tools commonly used are shown in Fig. 11–24. Digging starts with a short-handled shovel, shifts to a long-handled one, and finally ends with a digging spoon as the depth

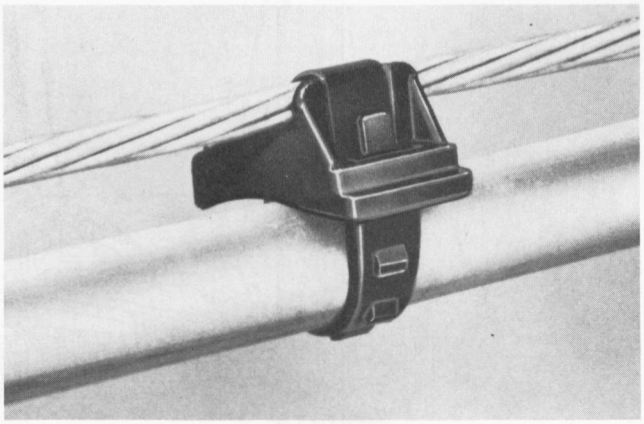


Fig. 11-21. Aerial support tie *(Anixter Bros., Inc.).*

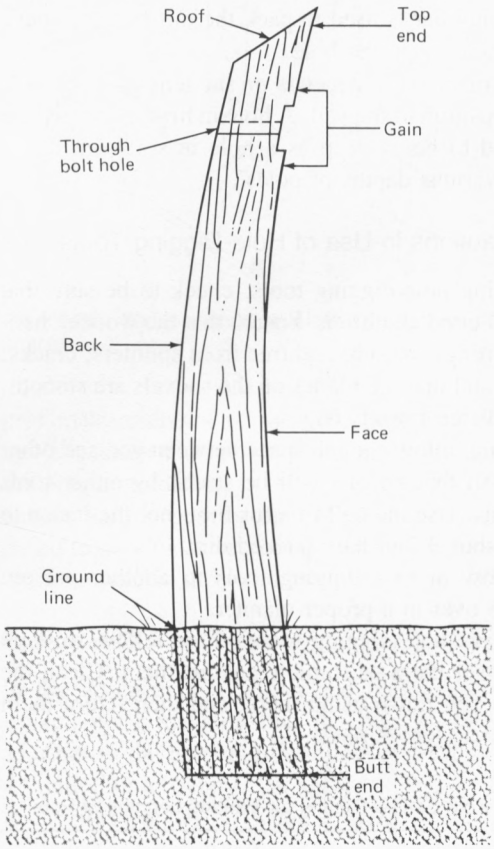


Fig. 11-23. Parts of a pole.

Fig. 11-22. Preformed grip (dead end).

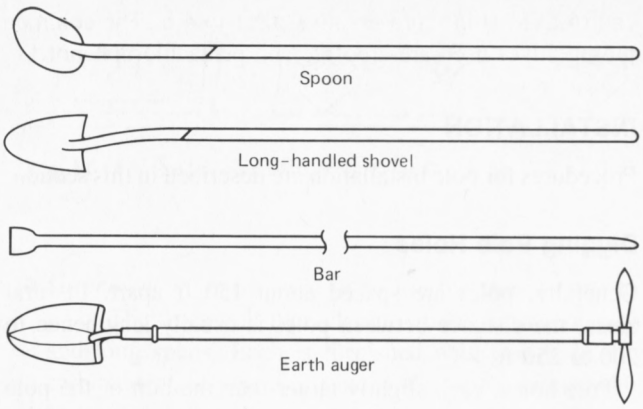


Fig. 11-24. Pole digging tools.

increases. Hard soil is broken up with a digging bar before digging begins. On smaller-diameter poles, the earth auger (Fig. 11-24) is used. Holes for poles should be of the same diameter from top to bottom. The diameter of the hole should always be large enough that a tamping bar can be worked on all sides between the pole and the sides of the hole. A tamping bar is used to pack the dirt tightly around the pole to secure it in the hole.

The depth of the hole depends on the length of the pole and the composition of the soil. A hole in firm, rocky terrain does not need to be as deep as a hole in soft soil. Table 11–2 shows various depths of poles.

Safety Precautions in Use of Hole-Digging Tools

1. Before using hole-digging tools, check to be sure that they are in good condition. Ensure that the wooden handles are strong, smooth, and free from splinters, cracks, and splits and that the blades on the shovels are smooth, sharp, and free from twist.
2. In shoveling, allow enough space between you and other shovelers so that no one will be struck by either tools or materials. Use the ball of your foot, not the instep to press the shovel into hard packed dirt.
3. Never throw or toss digging tools to another person; hand them over in a proper manner.
4. Do not leave hole-digging tools where fellow workers may trip over them or stumble against them. Clean the tools after you finish using them, and then return them to the proper storage place.

TABLE 11–2. Pole Setting Depths for Various Lengths of Pole

Length of Pole, ft	*Setting Depth in Soil, ft*	*Setting Depth in Rock, ft*
20	5.0	4.0
30	5.5	4.5
40	6.0	5.0
50	7.0	5.5
60	8.0	6.5
75	9.5	7.5
90	11.0	8.5

Setting Poles

Setting Poles in Sandy or Swampy Soil

A pole set in sandy or swampy soil must be supported by guys or braces or by "cribbing," or the placement of some firm material around the part of the pole that is below ground. In the method of cribbing shown in Fig. 11–25, a 6-ft section of pole is placed 18 to 24 in. below the ground on the strain side of the pole. At the bottom of the hole, rocks are placed on the side opposite the section of pole.

Setting Poles in Loose and Weak Soil

In weak or loose soil, the hole is made large enough to allow a barrel to be inserted. The butt of the pole is placed into the barrel and the barrel filled with concrete, sand, or rocks. The hole is filled and tamped down with a tamping bar. The purpose of the barrel is to present a larger surface, thus retarding "pullover" from the weight of cable and wires. Fig. 11–26 shows such an installation.

Setting Poles in Rocky Soil

When a pole is to be placed in rocky soil, a hole is blasted and the pole inserted. After insertion, rock or concrete is used to secure it in the hole.

Setting Poles by Winch

If a truck with winch and a boom is available, the job of erecting poles is simple. A sling is placed around the ap-

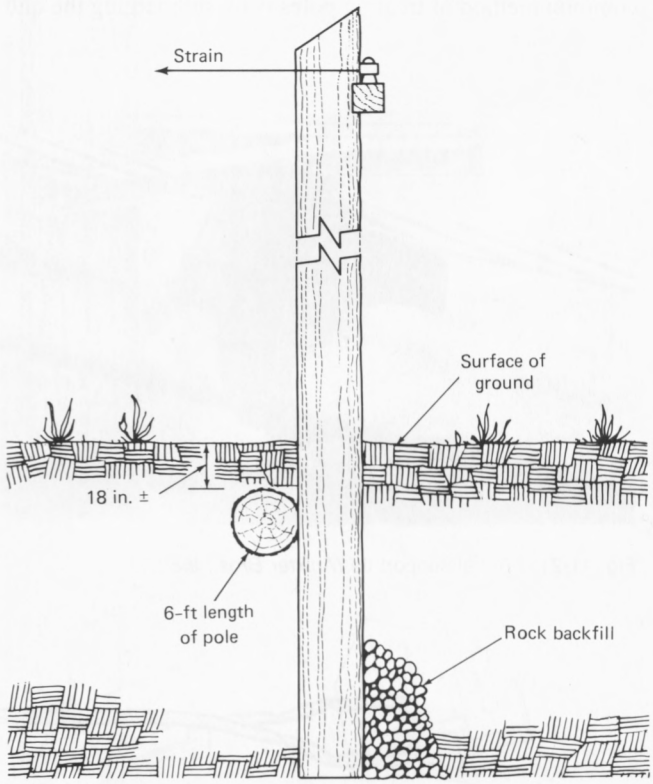


Fig. 11-25. Cribbing a pole.

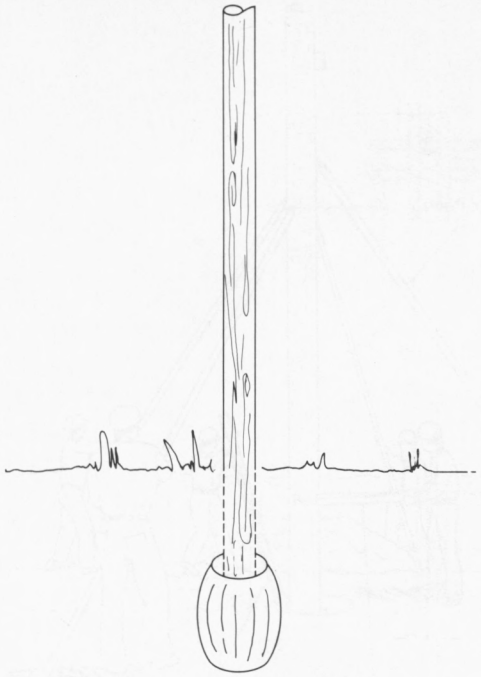


Fig. 11-26. Setting a pole using a steel pin.

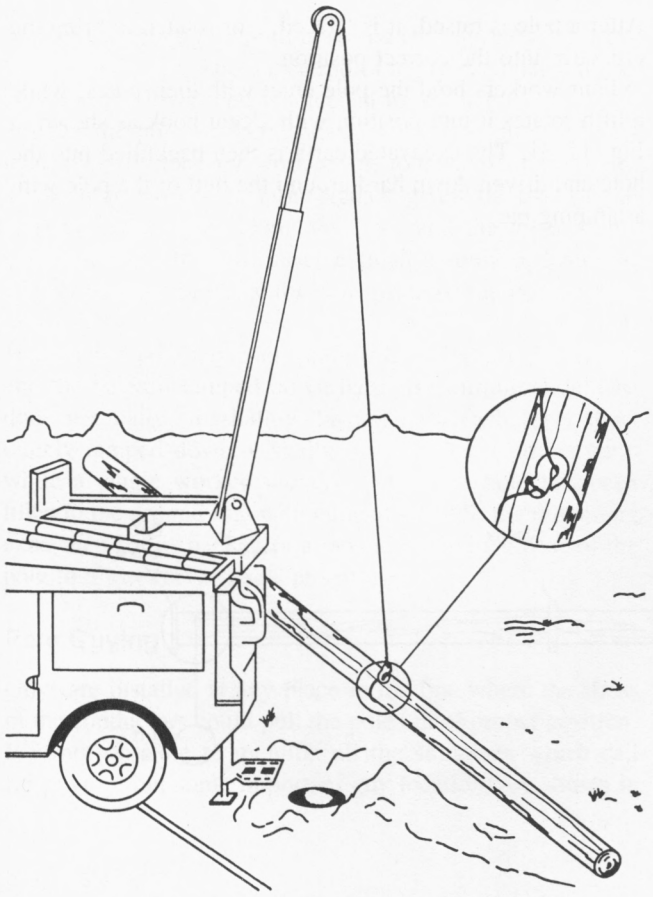


Fig. 11-27. Winch method of pole raising showing pole on the ground.

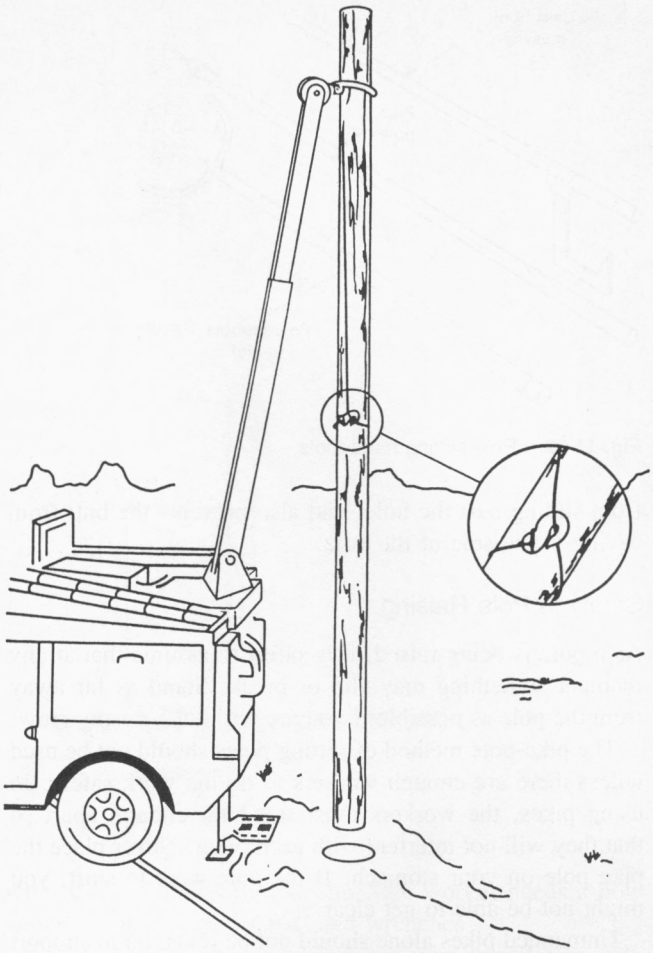


Fig. 11-28. Winch method of pole raising showing pole being placed in hole.

proximate midpoint of the pole, and the winch heaves it up. The truck then proceeds to the hole, and the base of the pole is guided in as the winch lowers away. Since the butt or base is heavier than the top end, the pole will be raised to an almost vertical position. The winch method of setting a pole is shown in Figs. 11–27 and 11–28.

Setting with Pike Poles

In the absence of a winch and boom, the pole may be ''piked up,'' meaning that the pole is placed with base adjacent to the hole and the upper end supported on either a ''mule'' or a ''jenny.'' A jenny is a wooden support made in the form of an X, while a mule is a wooden support made in the form of a Y. The upper end is then piked into the air by workers using pike poles. A pike pole and mule are illustrated in Fig. 11–29.

This procedure is illustrated in Fig. 11–30. The ''butt man'' holds and guides the butt of the pole with a cant hook or *peavey* (see Fig. 11–29). As the upper end of the pole is raised, a worker keeps the jenny in approximate contact by moving it toward the butt. The ''buttboard'' (Fig. 11–30) is a length of plank, set in the hole and long enough to protrude above the surface. It prevents the butt of the pole

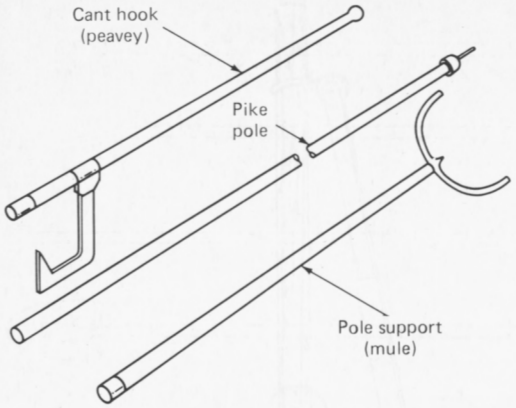


Fig. 11-29. Pole-setting hand tools.

from sliding past the hole, and also prevents the butt from caving in the side of the hole.

Safety in Pole Raising

As a pole is being raised, it is safest to assume that at any moment something may slip or break. Stand as far away from the pole as possible if you are not in the raising crew.

The pike-pole method of setting poles should not be used unless there are enough workers to do the work safely. In using pikes, the workers must stand far enough apart so that they will not interfere with each other. Never place the pike pole on your stomach. If the pole were to shift, you might not be able to get clear.

Unmanned pikes alone should not be relied on to support a pole while a worker is on it. Pike-pole tops should be kept covered at all times except when actually in use. Workers should not be on the pole while it is being straightened or tamped.

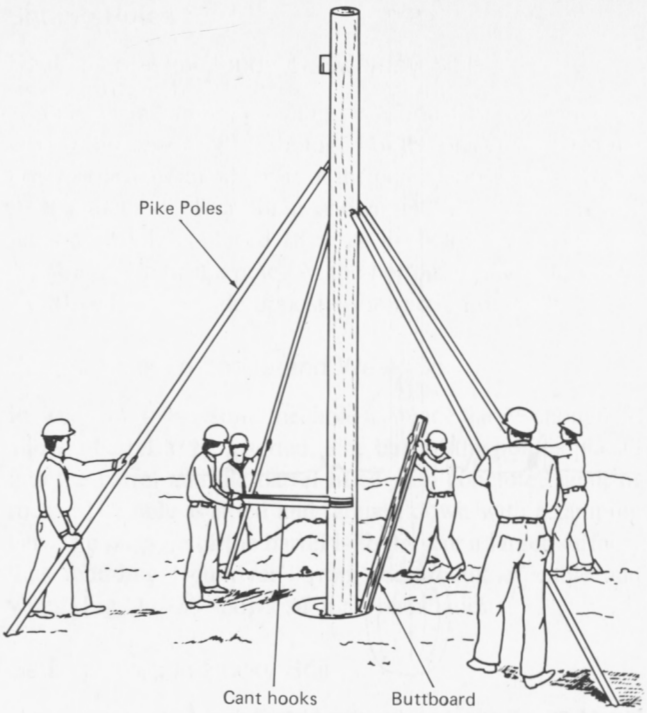


Fig. 11-31. Facing a pole by using hand tools.

Facing Poles

After a pole is raised, it is "faced," or rotated to bring the crossarm into the correct position.

Four workers hold the pole erect with their pikes, while a fifth rotates it into position with a cant hook as shown in Fig. 11–31. The excavated earth is then backfilled into the hole and driven down hard around the butt of the pole with a tamping bar.

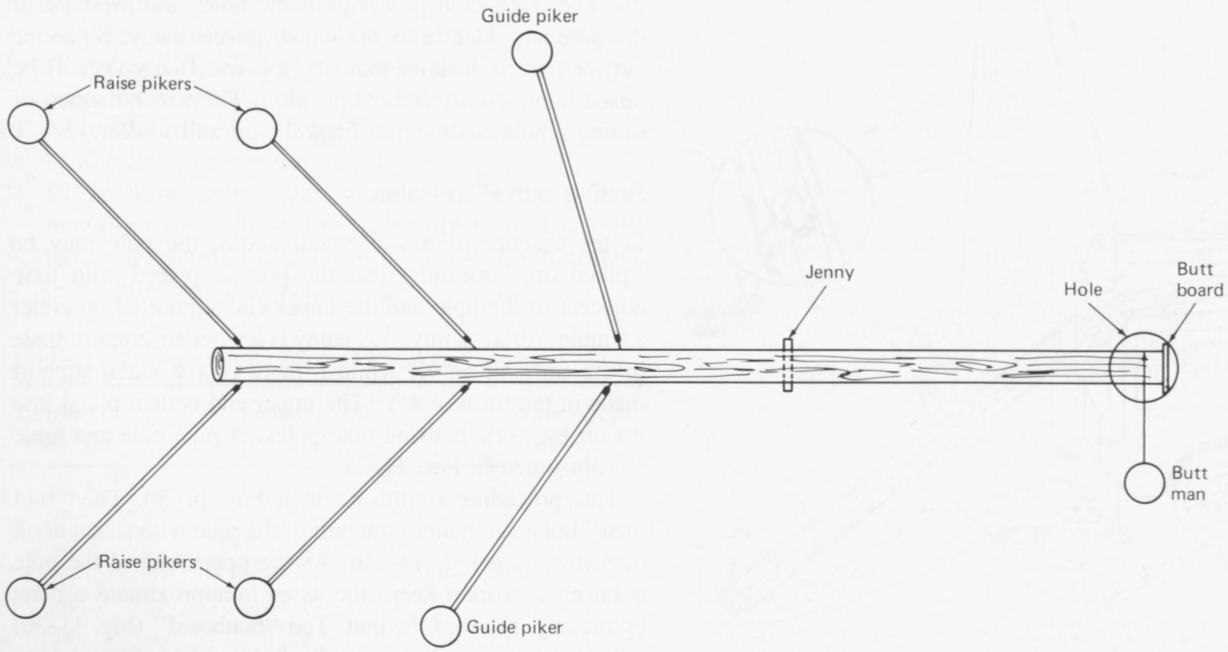


Fig. 11-30. Pike-pole method of pole raising.

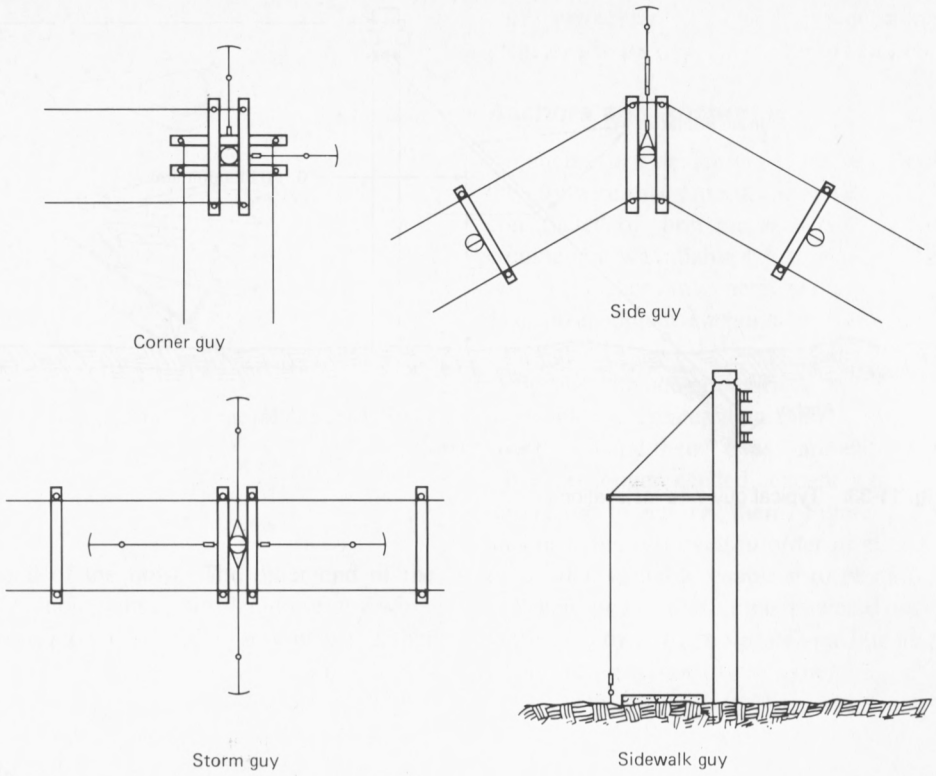


Fig. 11-32. Types of guys.

When necessary, a pole is secured in place by steel cables, called *guys*. The upper end of a guy is attached to the pole and the lower end is attached to an anchor.

After the pole has been faced, it must be plumbed vertical. This is done by workers on four sides of the pole. These four workers act on signals given by two of the workers. One sights along the line, and the other sights from one side. In some cases a small amount of lean (ca. 12 in.) remains to allow for wire strain or the normal give of a guy.

After the pole has been plumbed, the hole is backfilled and the backfill tamped down hard. Backfilling should be done gradually, in shallow layers, with each layer thoroughly tamped down. Usually two or three workers tamp while a single worker shovels. When the hole has been filled to the ground line with tamped backfill, the remaining excavated soil is banked in a mound around the base of the pole to allow for subsequent settling.

Pole Guying

Guys are installed at any place in the line where the stress of the conductors could pull the pole out of proper position. It is not possible to mention all the situations which call for guying, but some important guy locations are shown in Fig. 11–32.

Guy Assembly

The materials needed to assemble a guy include guy wire, insulators, and hardware or dead-end grips. To install a guy wire from the pole to the anchor, the worker needs a bolt cutter, a cable grip, a hoist, and wrenches.

Figure 11–33 shows a typical guy-wire installation. All guy wires used to support wooden poles are made up of steel strands. When guy wire is cut, both sides should be held firmly to prevent the free ends from flying up and causing an injury. Guy wires are installed by using prefabricated grips (Fig. 11–22) or guy-wire clamps (Fig. 11–12).

One method of connecting a guy to a pole is shown in Fig. 11–34. When two guy wires are placed on the same pole, one is placed near the top and the other installed midway down. Guy wires should never cross each other. Placement of an insulator in a guy is shown in Fig. 11–35. The two ends of the guy wire are first looped through the holes in the insulator, then fastened with guy clamps.

Tensioning Down Guys

Guy wires should be placed on the poles and tensioned before cables are installed. If the cables were installed first, the poles would be pulled out of position by the weight of the cable.

A guy wire is tightened by means of a hoist and grip, as shown in Figs. 11–36 and 11–37. The first step is to install a thimble eyebolt in the pole. The purpose of the bolt is to secure one end of the guy wire. Next, the workers install the anchor that will be used for this installation. The end of the guy wire is then inserted through the eye of the anchor and fastened with either a two- or three-bolt guy clamp. A cable grip is then placed on the guy wire and

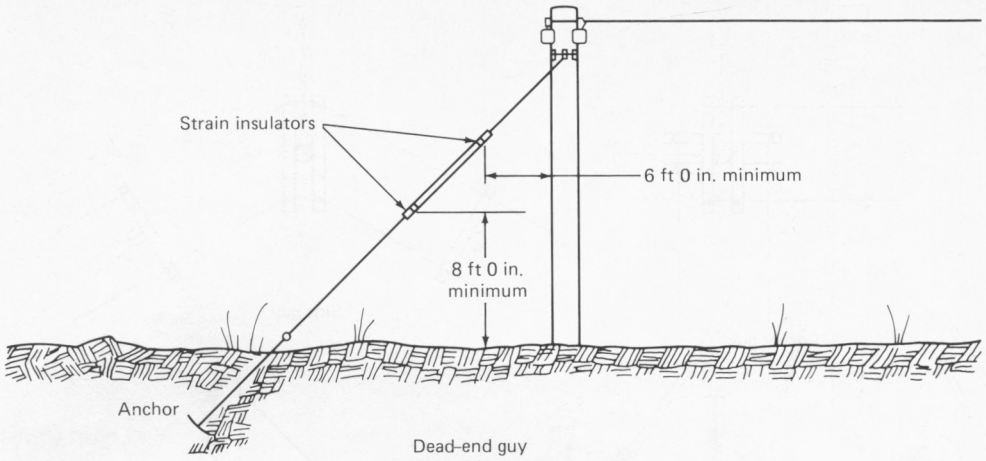


Fig. 11-33. Typical guy-wire installation.

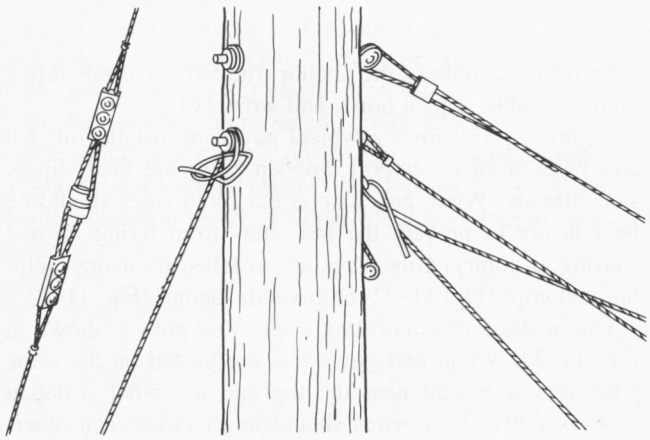


Fig. 11-34. A method of attaching guys to a pole.

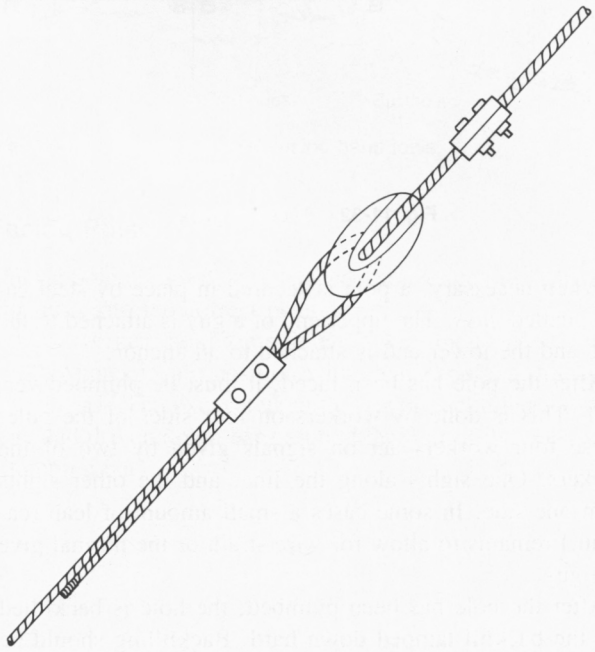


Fig. 11-35. Typical guy-wire insulator installation.

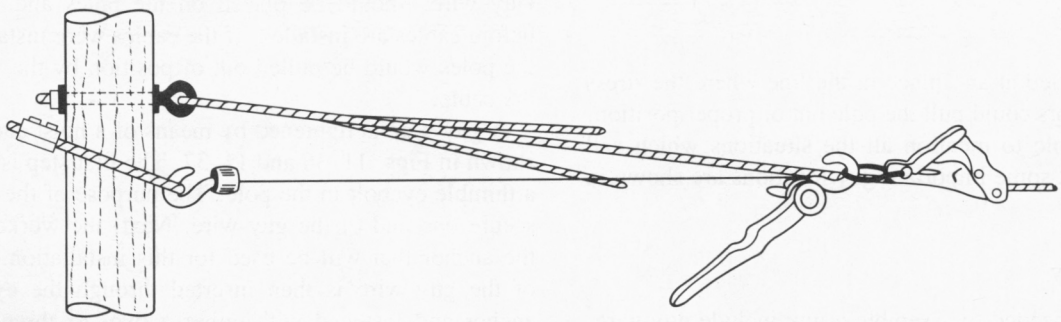


Fig. 11-36. Down guy tensioning.

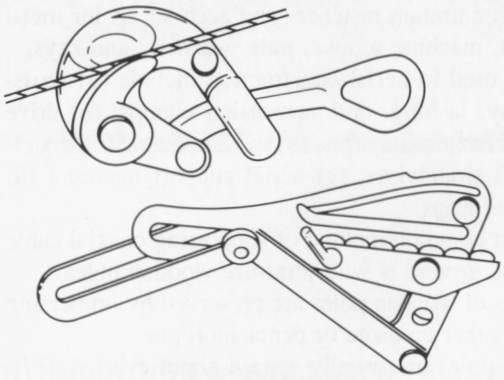


Fig. 11-37. Guy-wire grips, or come-alongs *(M/A Com Comm-Scope)*.

connected to one end of the hoist. The other end of the hoist is attached to the pole with a short length of guy wire.

The hoist is used to pull the pole and guy wire together until the pole starts to lean. At that time, the guy wire is cut, a preformed dead-end is placed in the thimble eyebolt, and its ends are twisted around the free end of the guy wire.

Anchors and Anchoring

An anchor is a device that holds or "anchors" one end of the guy wire that supports a wooden pole. Anchors may be constructed of short pieces of pole or may be one of the commercially available types. Figure 11–38 shows various types of anchors in general use within the CATV industry. The most popular anchor is the screw type shown in Fig. 11–38*d*.

Because anchors are buried, the expense of digging them up would be greater than their worth; therefore, they are abandoned and their "eyes" are cut off below ground level when no longer needed, except when screw anchors are unscrewed to retrieve them. Figure 11–39 shows a screw anchor being retrieved in order to eliminate the possibility of accidents, and to enable it to be reused.

Where practicable, a gas-powered auger, operated in reverse, together with a suitable anchor adaptor, may be used to unscrew anchors of this type.

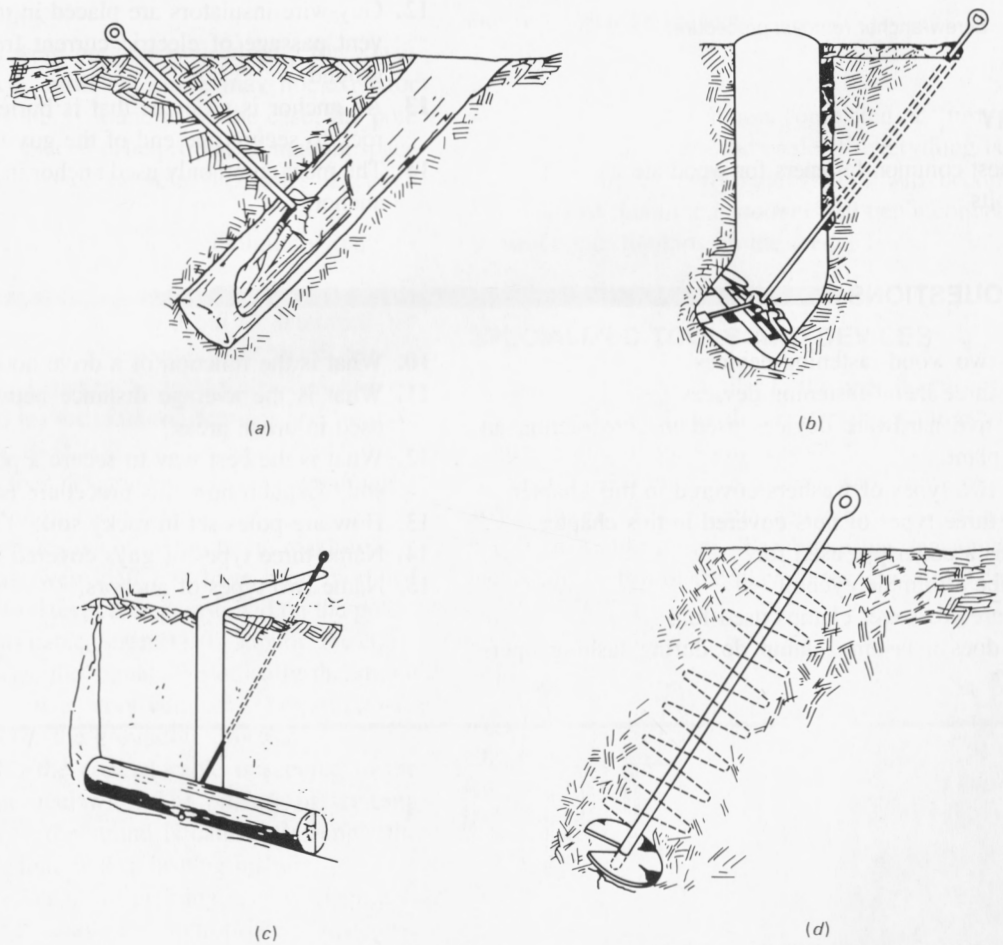


Fig. 11-38. Type of anchors: (*a*) never-creep anchor; (*b*) expanding anchor; (*c*) log anchor; (*d*) screw anchor.

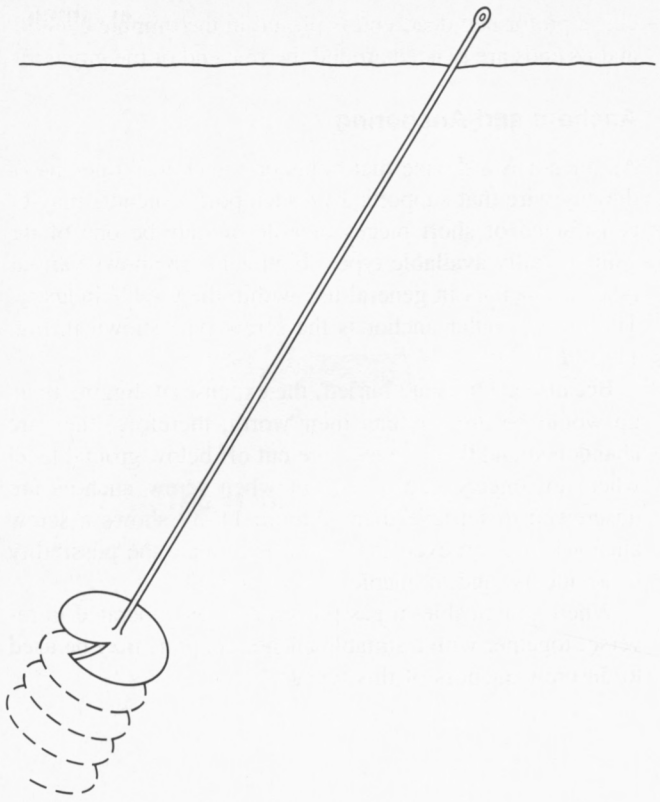


Fig. 11-39. Screw-anchor removal procedure.

SUMMARY

1. The most common fasteners for wood are nails, screws, and bolts.
2. The most common fasteners and accessories for metal are bolts, machine screws, nuts, washers, and keys.
3. Devices used in aerial construction include (*a*) crossover, guy, lashing, and suspension clamps; (*b*) drive hooks; (*c*) extension arms; (*d*) cable spacers; (*e*) strandlinks; (*f*) strandvises; (*g*) aerial support ties; and (*h*) preformed grips.
4. The most common method of supporting coaxial cable above the ground is with joint-use wooden poles.
5. The butts of wooden poles are preserved by immersing them in either creosote or pentachlorophenol.
6. Wooden poles are usually spaced about every 150 ft. in urban areas.
7. Hand tools used to dig holes for poles are (*a*) the digging spoon, (*b*) the long-handled shovel, (*c*) the short-handled shovel, and (*d*) the digging bar.
8. Various methods of setting poles in weak, sandy, swampy, or loose soil include (*a*) using a barrel filled with concrete and (*b*) cribbing with a section of pole and backfilling with rock.
9. Poles may be placed into a hole by either raising it with a winch and boom or by piking it in.
10. Facing a pole is done with cant hooks and pikes.
11. A guy is a wire support that extends from the pole to an anchor.
12. Guy-wire insulators are placed in the guy wire to prevent passage of electric current from the pole to the ground.
13. An anchor is a device that is buried in the ground or rock to secure one end of the guy wire.
14. The most commonly used anchor in CATV is the screw anchor.

REVIEW QUESTIONS

1. Name two wood-fastening devices.
2. Name three metal-fastening devices.
3. Name five hardware devices used in constructing an aerial plant.
4. Name two types of washers covered in this chapter.
5. Name three types of nuts covered in this chapter.
6. What is a cotter pin used for?
7. Describe a thimble eyebolt.
8. What are crossover clamps used for?
9. What does a lashing clamp do during lashing operations?
10. What is the function of a drive hook?
11. What is the average distance between wooden poles used in urban areas?
12. What is the best way to secure a pole in soft or sandy soil? Explain how this procedure is performed.
13. How are poles set in rocky soil?
14. Name three types of guys covered in this chapter.
15. Name two types of anchors.

12
CHAPTER
LASHED-CABLE CONSTRUCTION

INTRODUCTION

In this chapter you will learn about:

1. The specialized tools used to place strand cable and coaxial cable on poles
2. How strand cable is placed on the pole
3. How the coaxial cable is lashed to the strand cable

The installation of coaxial cable on utility poles, known as *aerial plant,* is the most popular method of providing CATV service. On a pole jointly used by the CATV, telephone, and power companies, the power company lines will be located at the top of the pole. Below the power company lines are the CATV cables, and 12 in. below these are the telephone company lines.

Because the poles were previously used only for power and telephone service, sufficient space may not exist for CATV cables. When this is found to be the case, the pole is either modified or replaced. The process of making space available for CATV service on joint-use poles is called "make-ready."

Installation of CATV service in a community requires the following steps:

1. The area to be served is mapped out to determine (*a*) the total number of poles needed for the plant, (*b*) the number of potential homes or apartments that will require service, and (*c*) the distance between and location of each pole to be used.
2. A cable system is then designed to serve the community, based on the mapping process.
3. The owner of the poles is notified to begin make-ready.
4. Once all poles that were deficient have been modified or replaced, a ¼-in. steel cable is installed on the poles. The purpose of this cable (strand) is to support the coaxial cable that carries the signal. Periodically the strand is grounded to eliminate stray voltages. The term *bonding* is used to denote the grounding process.
5. When all is ready, the coaxial cable is secured to the strand with a thin steel wire. The process of securing the coaxial cable to the strand is called "lashing" the cable. Lashing is done with a lashing machine.
6. After the coaxial cable has been hung, a crew of splicers cuts the cable and installs the appropriate connectors. Connectors are installed so that amplifiers, taps, and splitters may be placed in the cable.

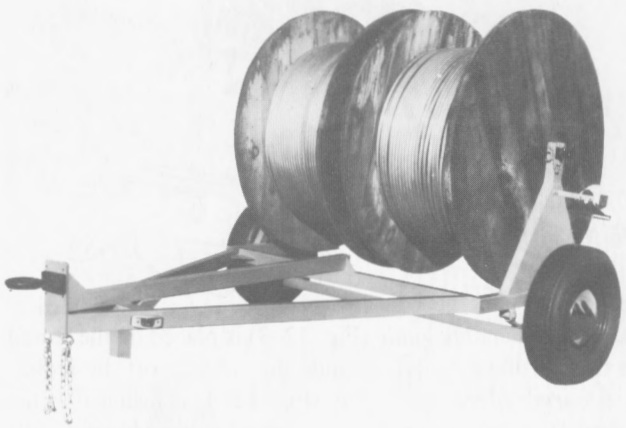


Fig. 12-1. Reel trailer (*Lemco Tool Corp.*).

7. After a section of plant is completed, a "turn-on" crew injects a signal into the cable. If everything is found to be working properly, the system will become operational. At this time *installers* will begin connecting subscribers to the taps on the feeder lines.

SPECIALIZED TOOLS AND DEVICES

A *cable reel trailer,* similar to the one shown in Fig. 12–1, is available from many different manufacturers and ranges from the type shown to more sophisticated units capable of carrying three or more reels at the same time. A reel brake assembly (Fig. 12–2) is attached to the cable reel supporting bar of the cable trailer. The brake has tensioning adjustments for control of the playout tension of the cable.

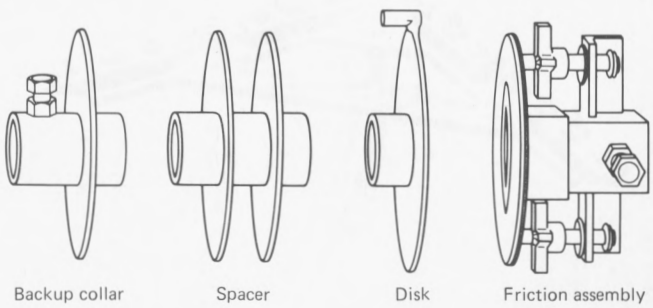


Fig. 12-2. Reel brake assembly (*M/A Com Comm-Scope*).

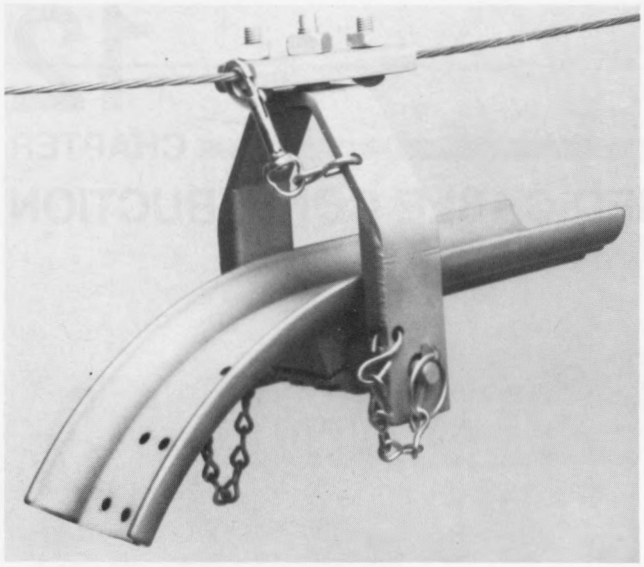


Fig. 12-3. Cable chute (*Lemco Tool Corp.*).

The *aerial cable guide* (Fig. 12–3) is placed on the strand in front of the cable(s) to guide the cable(s) off the reels.

A *corner block attachment* (Fig. 12–4) is fastened to the strand at corners to support 45 and 90° corner blocks (rollers).

A *45° corner block* is used at locations where the cable turns 5 to 45°. It protects the cable from being damaged by the severe bending radii and maintains proper cable separation when multiple cables are being pulled.

A *90° corner block* is used at locations from 45 to 90° and serves the same purpose as the 45° degree corner block described above. Figure 12–5 shows a 90° corner block.

A *multiple cable positioner* is placed on the strand cable in front of the cable lashing machine, and the coaxial cable is placed into it. As the lashing machine is pulled span by span, the cable positioner feeds the coaxial cable into the lashing machine, thereby maintaining a uniform positioning of the cables. A cable positioner is shown in Fig. 12–6.

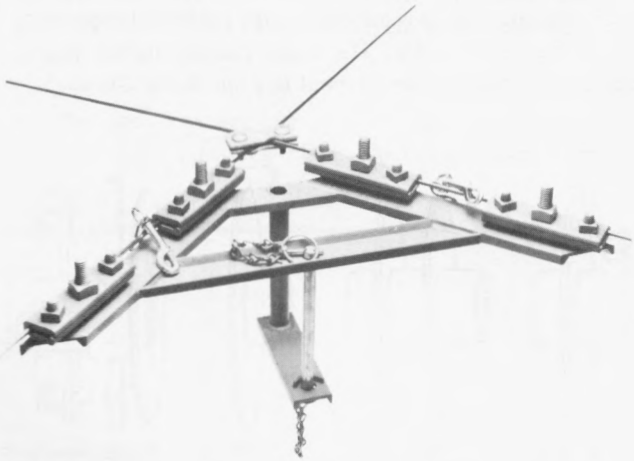


Fig. 12-4. Corner block attachment (*Lemco Tool Corp.*).

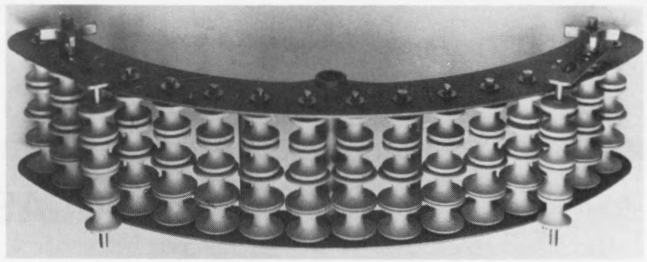


Fig. 12-5. 90° corner block (*Lemco Tool Corp.*).

A *strand chute bracket* is utilized in conjunction with a 45° corner block for receiving the cable from the reel trailer. A strand chute bracket is shown in Fig. 12–7.

The *pole attachment bracket,* shown in Fig. 12–8, is utilized to anchor the 45 and 90° corner blocks securely to a pole.

The *multiple cable puller* (Fig. 12–9) is a device used to separate up to four cables as they are pulled into place for lashing. The cables are first placed in pulling grips. The pulling grips are then secured to the eyelets of the puller.

Multiple cable blocks (rollers) are used in the same manner as single-cable blocks. They are available in configurations to accommodate 2 to more than 10 cables. A multiple cable block is shown in Fig. 12–10.

A *cable block rod* such as the one shown in Fig. 12–11 is a ¼-in. smooth steel rod approximately 16 in long. These rods are clamped in the suspension clamps at the poles for supporting standard cable blocks.

A *cable lifter head* is a tool used on the end of layup sticks for placing the cable into the cable blocks at midspan locations without damaging the cable. Figure 12–12 shows a typical cable lifter head.

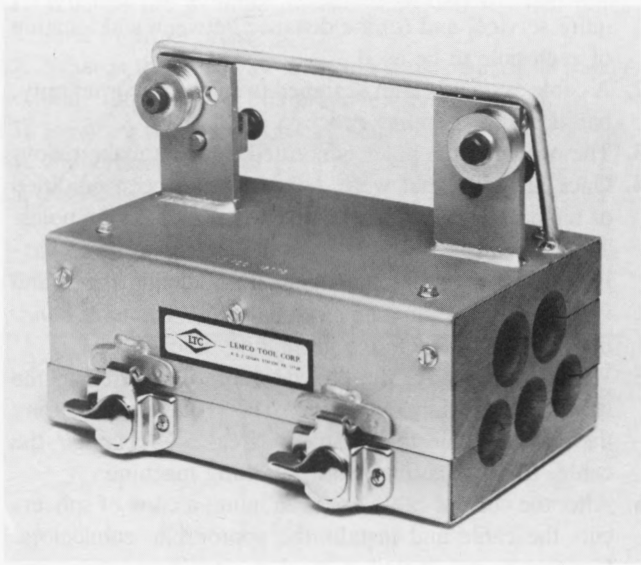


Fig. 12-6. Multiple cable positioner (*Lemco Tool Corp.*).

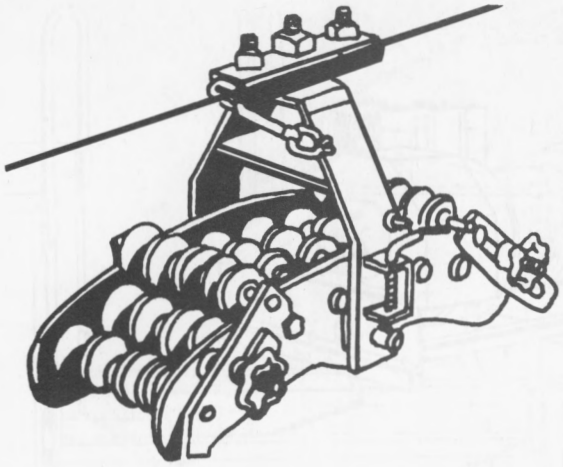


Fig. 12-7. Strand chute bracket (*M/A Com Comm-Scope*).

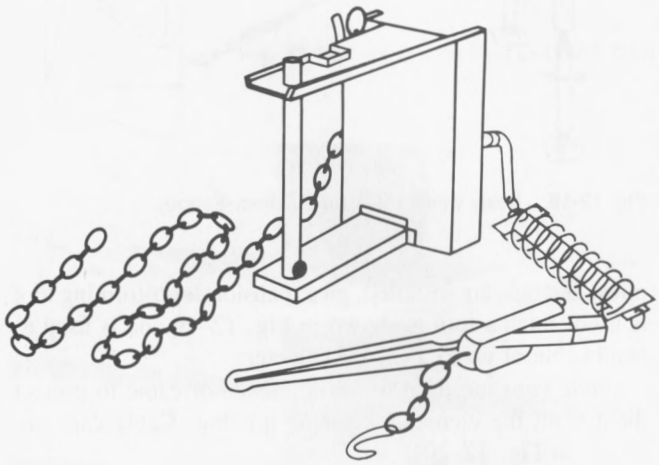


Fig. 12-8. Pole attachment bracket (*M/A Com Comm-Scope*).

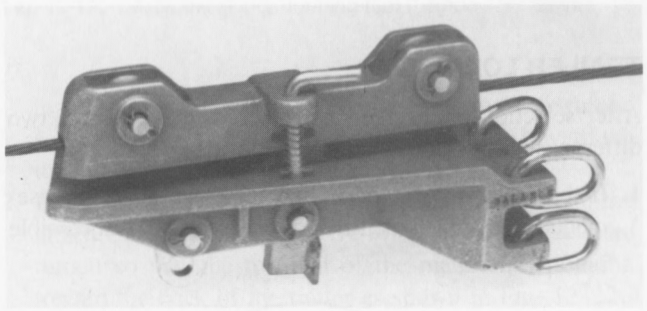


Fig. 12-9. Cable puller (*Lemco Tool Corp.*).

Lashing Machine

Figure 12–13 shows a cable lashing machine. The lashing machine wraps either a single or double 0.045-in. stainless-steel wire around both the coaxial cable and strand cable. There are two basic sizes of lashers used. The C lasher will accommodate cable bundles of up to 1½-in. diameter; others are available for cable bundles of up to 3¼ in. Each lasher

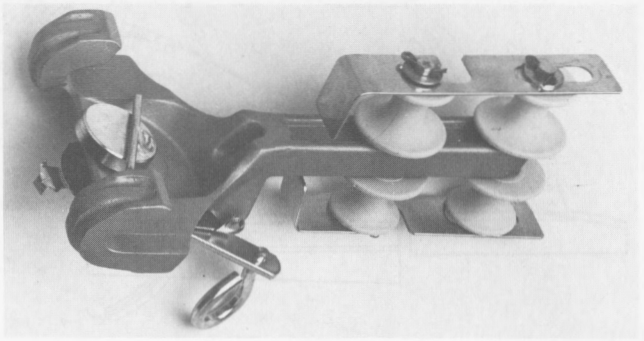


Fig. 12-10. Multiple cable block (*Lemco Tool Corp.*).

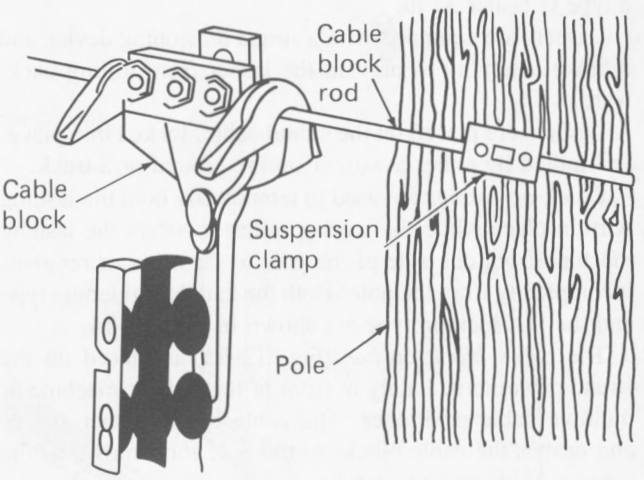


Fig. 12-11. Cable block rod (*M/A Com Comm-Scope*).

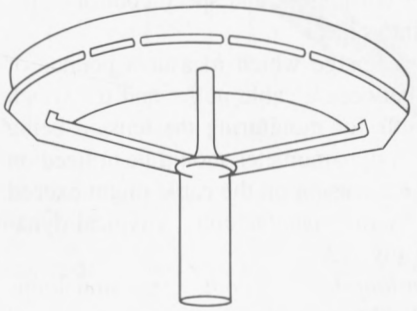


Fig. 12-12. Cable lifter head (*M/A Com Comm-Scope*).

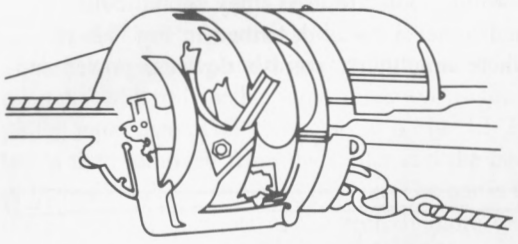


Fig. 12-13. Lashing machine (*M/A Com Comm-Scope*).

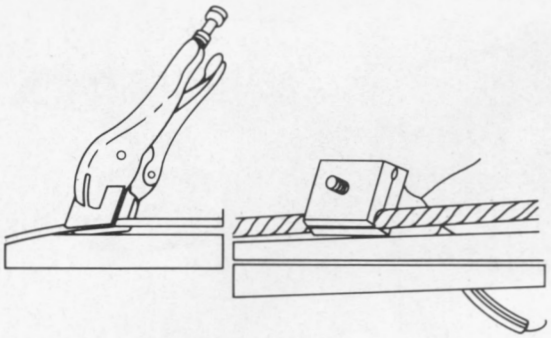


Fig. 12-14. Catch-off clamp (*M/A Com Comm-Scope*).

holds two 1200-ft coils of wire, making the total weight of a type C lasher 33 lb.

Lashers are equipped with a strand tensioning device and a brake assembly to prevent the lasher from rolling backward.

Lashers are placed on the strand cable, locked into place, and pulled by either a worker on the ground or a truck.

Catch-off clamps are used to temporarily hold the lashing wire in place while the worker either transfers the lashing machine from one side of the pole to the other or removes it completely from the pole. Both the handle-tightening type and the self-locking type are shown in Fig. 12–14.

The *cable block pusher* (Fig. 12–15) is placed on the strand cable immediately in front of the lashing machine or multiple cable positioner. The cable block pusher spaces and pushes the cable blocks to the pole for removal as the cable is being lashed span by span.

A *winch* (Fig. 12–16) is equipped with heavy-duty cable and its own engine. The winch can be mounted on trucks, pickups, or vans. It is utilized for pulling multiple cable configurations, proper tensioning, and speed control of the cable as it is pulled into place.

A *dynamometer* is a gauge which measures pounds of tension. It is placed between a cable puller and the winch line on long cable pulls for monitoring the tension being placed on the cables. A dynamometer should be utilized on all cable pulls where the tension on the cable might exceed levels recommended by the manufacturer. A typical dynamometer is shown in Fig. 12–17.

With an *expansion-loop-forming tool,* expansion loops are formed in coaxial cable to allow for the expansion and contraction of the cable with temperature changes. In all cases, expansion loops should always be formed with a tool designed for the purpose, and never by hand. If locally fabricated forming tools are used, they should conform to the shape and dimensions as described in Fig. 12–18. At locations where amplifiers, passive devices, power supplies, and taps are installed, an expansion-loop-forming tool is used. Such a tool is shown in Fig. 12–19 and is used to bend cable of up to 1 in. in diameter.

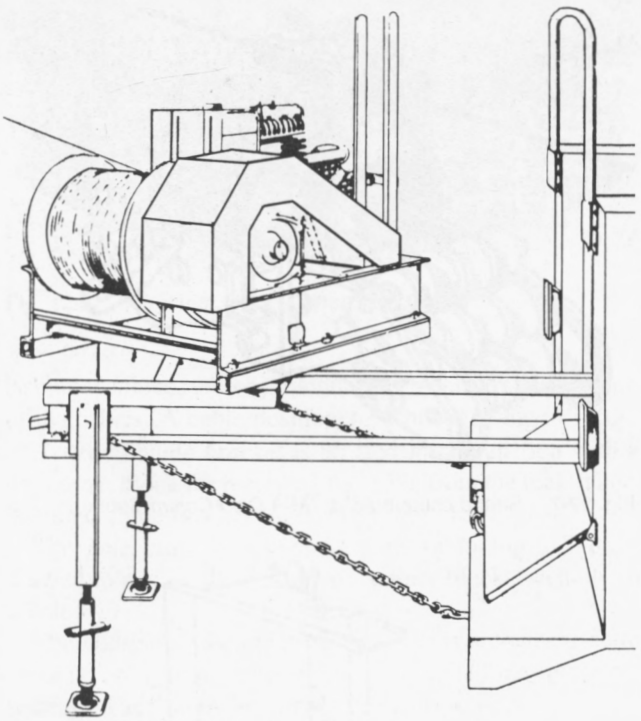


Fig. 12-16. Utility winch (*M/A Com Comm-Scope*).

Cable caps are used to seal the ends of cable to protect them from the elements prior to splicing. Cable caps are shown in Fig. 12–20.

A J hook is used in CATV aerial construction to secure figure-8 cable (integrated messengered cable) to the pole. A J hook is shown in Fig. 12–21.

TRAILER LOADING

After selection of the reels of material to be placed, two different reel positions should be considered:

1. If the material is to be pulled off the reel along easements, over other facilities or into areas not accessible

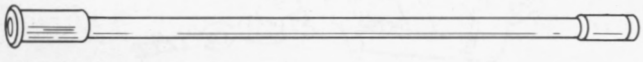


Fig. 12-15. Cable block pusher (*M/A Com Comm-Scope*).

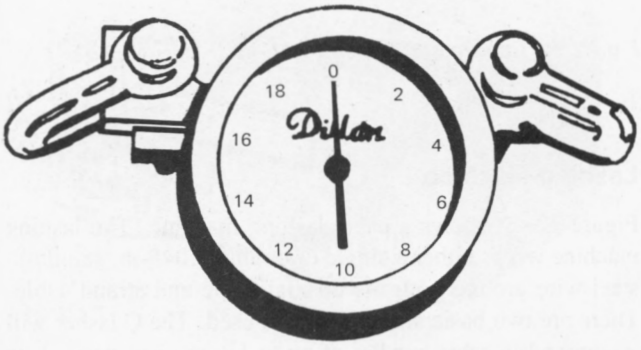


Fig. 12-17. Typical dynamometer (*M/A Com Comm-Scope*).

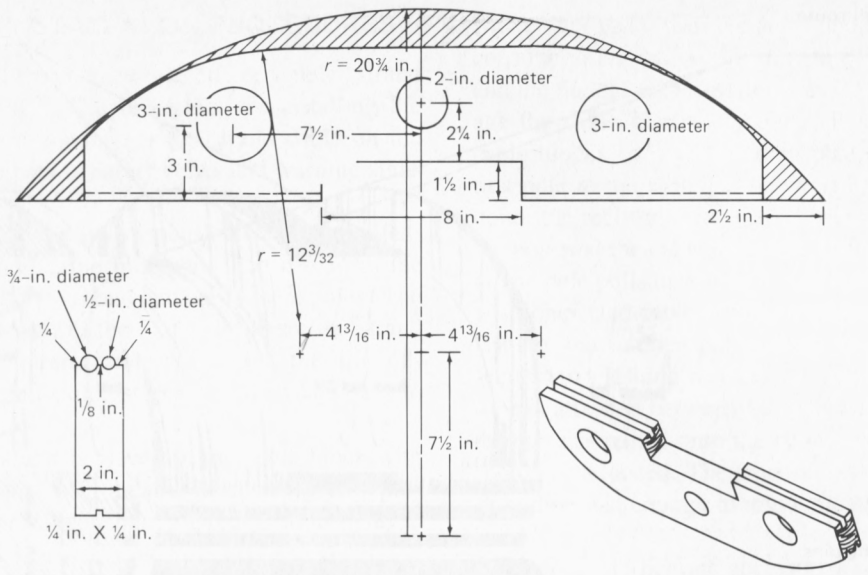


Fig. 12-18. Expansion loop tool (*M/A Com Comm-Scope*).

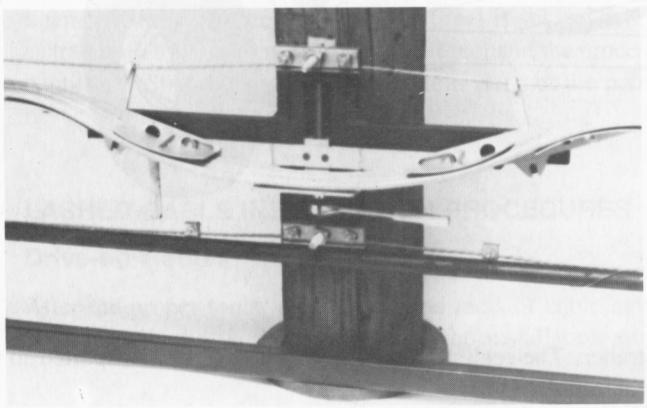


Fig. 12-19. Mechanical loop-forming tool (*Lemco Tool Corp.*).

to vehicles (called *back-pull routes*), the reels are turned so that the top end of the material is pointing toward the tongue of the trailer when loaded.

2. If the material on the reel will roll off directly onto the attachment point (called *drive-off routes*), the reels are turned so that the top end of the material is pointing toward the back of the trailer as shown in Fig. 12–22.

NOTE When loading more than one heavy reel onto the trailer, a between-reel support post is required for proper reel support.

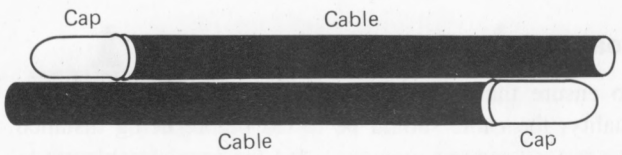


Fig. 12-20. Cable caps (*M/A Com Comm-Scope*).

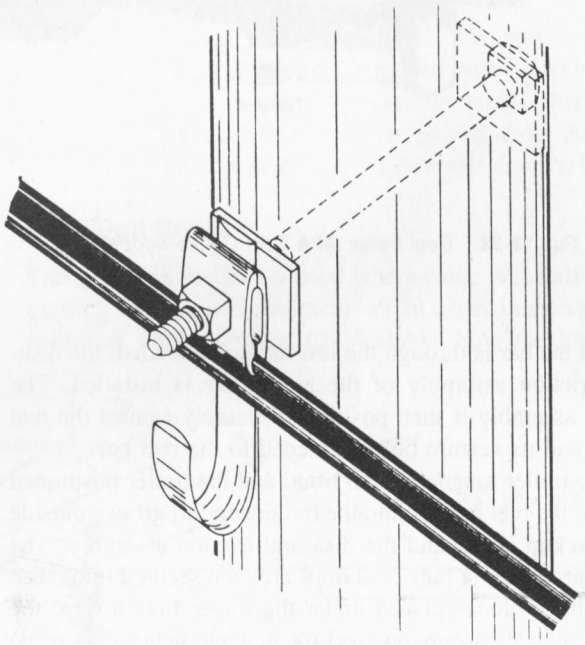


Fig. 12-21. J-Hook suspension clamp (*M/A Com Comm-Scope*).

After the reels have been positioned according to procedure 1 or 2 above, the reels are then aligned so that the center holes of the reels match. This alignment allows a reel support bar to be pushed through all reels to be loaded. This reel positioning and alignment process also assures that all reels will roll in the same direction as the cables are pulled into place. This can be seen in Fig. 12–22. The reel bar is then removed from the trailer and the backup collar of the reel brake is slid onto the bar. The bar is then placed through the center hole of the reel. If more than one reel is to be loaded, a reel spacer is placed between the reels.

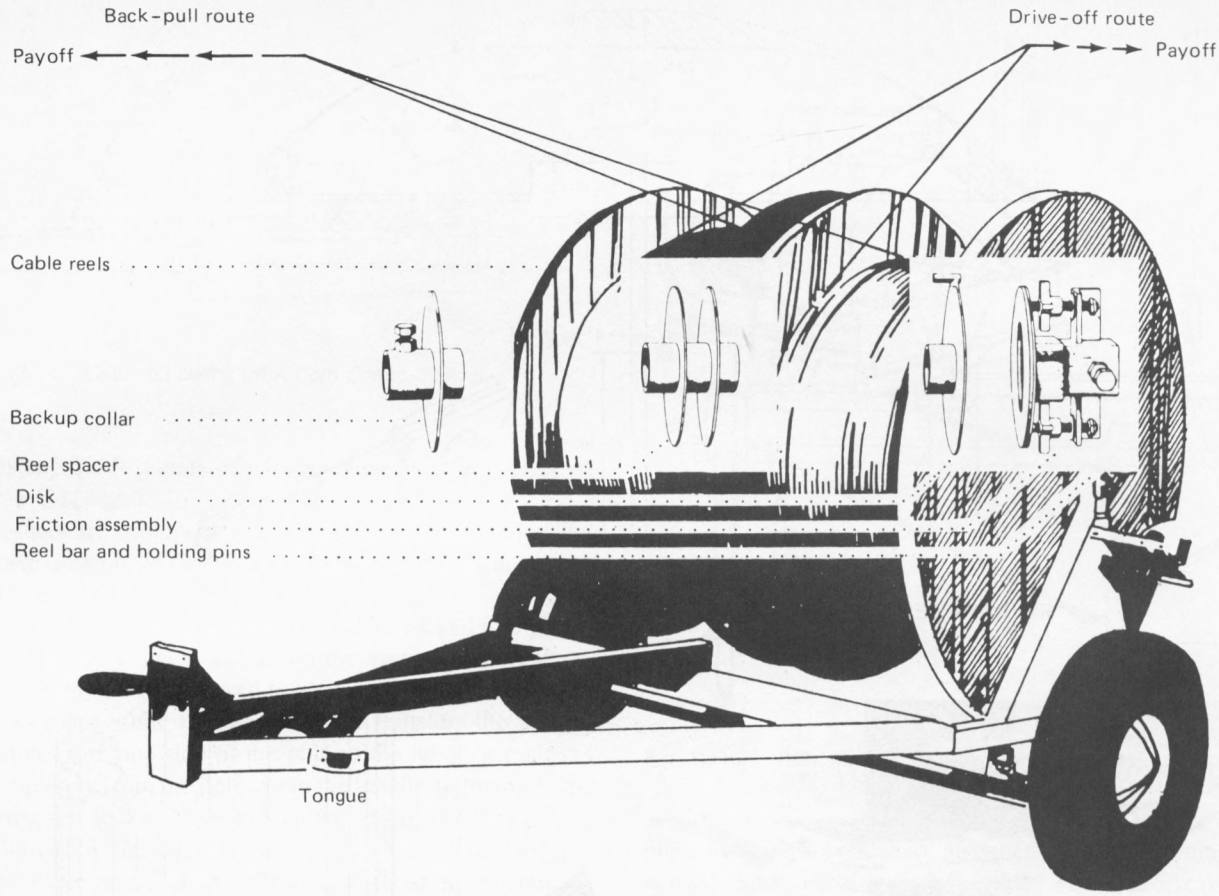


Fig. 12-22. Reel trailer (*M/A Com Comm-Scope*).

When the bar is through the last reel to be loaded, the disk-and-friction assembly of the reel brake is installed. The brake assembly is then positioned securely against the reel sides and its seizure bolts tightened to the reel bar.

The trailer tongue is then lifted and the trailer positioned so that the reel bar fits into the trailer support groove outside the backup collar and the disk-and-friction assembly. The reel bar fastening pins or clamps are then secured into place and chock blocks placed under the trailer tires toward the trailer tongue. If only one reel (or multiple lightweight reels) is (are) loaded onto the reel bar, two crew members can generally pull the trailer tongue down and connect it to the vehicle.

When heavy reels are loaded onto the reel support bar, a chain is connected to the trailer hitch on the vehicle and to the tongue on the trailer. One crew member then stands on each side of the trailer tongue in order to stabilize it. The vehicle is then pulled forward slowly. When the tongue is almost level with the back of the truck, a crew member places a block under the trailer tongue at the approximate height of the trailer hitch. When the vehicle backs up, the chain is removed and the trailer is connected to the vehicle. The brake pressure on the friction assembly is then adjusted to prevent free movement of the reels on the reel bar and the chock blocks are removed from under the wheels of the trailer. The reel(s) is (are) now ready to be transported to the installation site.

NOTE The protective covers are always left on the cable reels until they arrive at the installation site.

Partial Reels

Where partially filled coaxial cable reels remain at the end of the route, secure the cable to the reels as follows:

1. Pull all loose cable off the reel and reroll it back onto the reel, making sure that the wraps do not cross each other, and then cap and seal both ends.
2. Fasten the cable ends to the inside flanges of the reel securely with a staple to prevent movement during transport of the trailer.
3. If the balance of the cable on the partial reels is not used, avoid storing them on their sides or where the reel flanges might overlap each other.

Coaxial Cable Testing

To ensure that coaxial cable is not damaged or of poor quality, the cable should be tested before being installed. The test procedures recommended for coaxial cable are located in App. B.

STRAND CABLE INSTALLATION PROCEDURES

Before the coaxial cable can be placed on a pole, strand cable must be installed. The procedure for installing the strand begins with the loading of the strand cable on the reel trailer and placement of safety cones and warning signs along the route.

Each pole is then drilled and suspension clamps installed. A cable block rod and cable block are then placed in the suspension clamps of the second and subsequent poles. The reel trailer is then driven to the first pole where the strand is secured. After the strand cable is secured, the trailer is driven past the second pole, stopped, and backed up to relieve the tension.

At this time the strand is placed in the cable block with a lay-up stick equipped with a cable lifter head. This procedure is repeated at each pole until the reel is almost played out.

The cable blocks and rods are then removed and the strand placed into the suspension clamps and tightened manually. When this is completed, the strand is winched to the proper tension and the clamps tightened by using a lineman's wrench. The end of the first reel is spliced using a strandlink to the beginning of the next reel and the process continued. Splicing of the strand cable is done at the pole, never at midspan.

LASHED-CABLE INSTALLATION PROCEDURES

Drive-off Routes

After the proper tools, equipment, and reels of cable have been loaded, the workers proceed to the installation site, where they place warning signs and safety cones along the construction route. At this time the reel covers are removed and the flanges inspected for imperfections that would damage the cable during unreeling. Pushers, positioners, and cable blocks (rollers) are then placed on the strand at the first pole in the route as shown in Fig. 12-23. After this is done, the reel trailer is moved approximately 50 ft beyond the pole and the cable unreeled. Using a handline, a worker on the pole pulls up the cable and feeds it through the roller, positioner, and cable lashing machine. The loose end of the lashing wire is then pulled from its reel on the lasher and secured to a lashing wire clamp. After that is done, a pulling rope is attached between the lasher and the vehicle. Before the cable is pulled onto the strand, the reel brake assembly should be adjusted. The amount of tension on this assembly should be just enough to allow the reel to be turned by one hand.

When the lasher and accessories reach the next pole, the vehicle stops. A crew member then climbs the pole, secures the lashing wire, and transfers the lasher and accessories to the next section of strand cable. After the lasher and accessories are transferred, a loop-forming tool is used to make an expansion loop in the cable. The process of securing the lashing wire, transferring the lasher, and forming the expansion loop is continued until the reel is played out. The ends of the cable are then capped and about 30 in. of undamaged cable from the old and new reel are overlapped.

Back-Pull Route

The back-pull method is used where cable is installed over existing facilities or easements or in areas inaccessible to vehicular traffic. Figure 12-24 shows how the back-pull

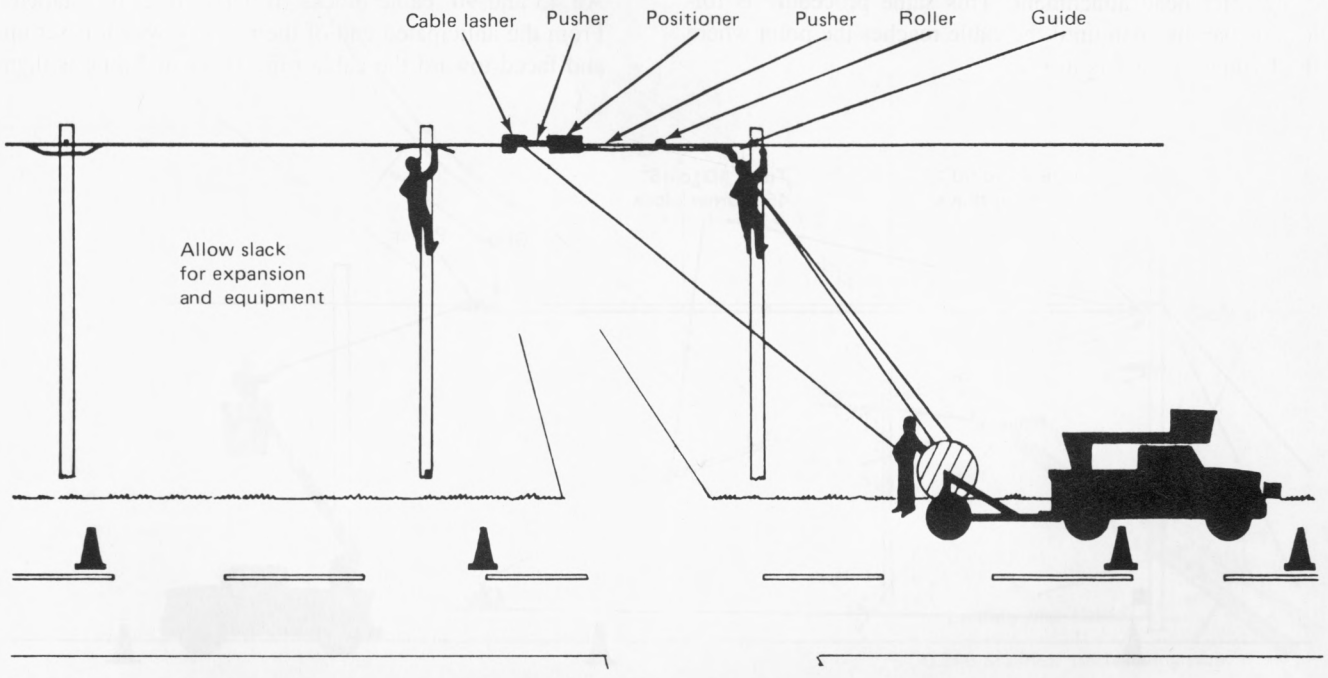


Fig. 12-23. Lashed cable—drive-off route procedures (*M/A Com Comm-Scope*).

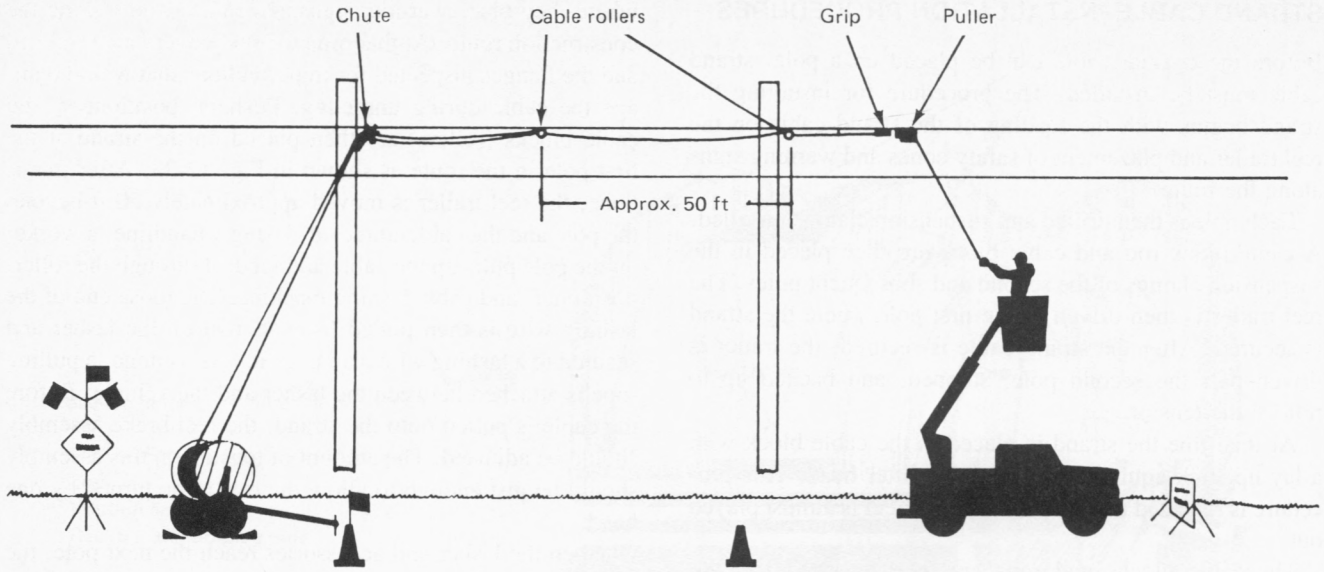


Fig. 12-24. Lashed cable—back-pull route procedures (*M/A Com Comm-Scope*).

method of cable installation is made. In this method, the reel trailer is unhooked from the vehicle and its tongue pointed in the direction of playout. The trailer is then placed approximately 50 ft from the first pole and its wheels are chocked. The safety equipment is then placed along the route of the installation. At this time a strand chute bracket is installed on the first pole along with a 45° corner block. At the same time a cable puller, if used, is installed onto the strand. A rotating-eye pulling grip is then placed over the coaxial cable and attached to the cable puller. Cable blocks are now placed on the strand every 50 ft and the cable is placed into them by using a lay-up stick with a cable lifter head attachment. This same procedure is followed span by span until the cable reaches the point where the lashing process is to start.

As the cable is pulled at locations where the cable must make turns of 10 to 45°, a 45° corner block assembly is installed on the strand or pole. The 90° corner block is utilized at all locations greater than 45°. Figure 12-25 shows how a turn is made during installation of coaxial cable on a utility pole.

If conditions dictate that the length of the route or number of cables being pulled requires the use of the winch, the following procedures are followed:

1. All cable blocks are placed on the strand for the entire length of the run by use of the cable block lifting tool. All 45 and 90° cable blocks (rollers) are also installed. From the anticipated end of the run, the winch is set up and faced toward the cable run. The winch line is then

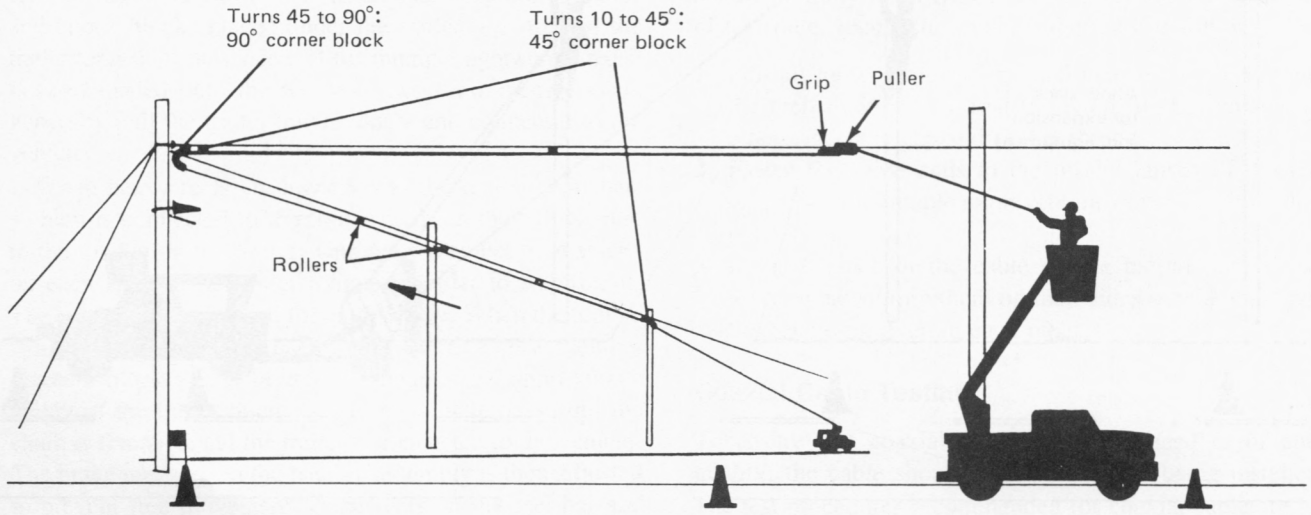


Fig. 12-25. Lashed cable—turn procedures (*M/A Com Comm-Scope*).

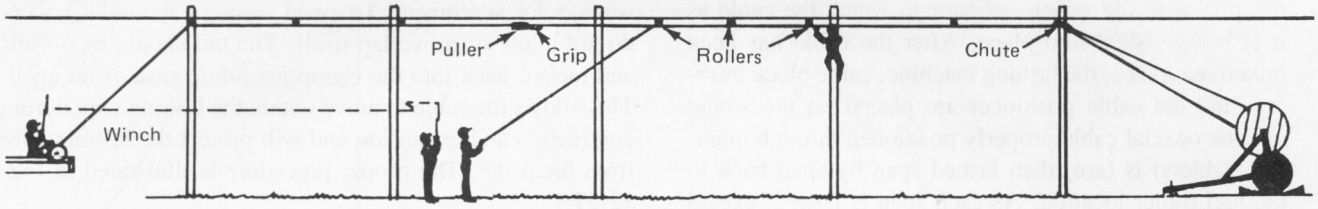


Fig. 12-26. Lashed cable—winching procedures (*M/A Com Comm-Scope*).

strung along the cable run and placed over all the cable blocks at all nonstress locations. At points of stress, *steel, winch line blocks* are used to avoid damage to the rubber or plastic rollers on standard cable blocks.

2. After the winch line has been connected to the cable or cable puller, the winch operator tensions the winch line according to individual cable specifications. A dynamometer should be utilized on all long cable pulls or where the tension on the cable might exceed the cable manufacturer's specifications.
3. The cable should be pulled into place with the winch, span by span, to the point where the lashing will start. When using the cable puller, the cable rollers are removed and replaced as the puller passes. Figure 12-26 shows the winch method of pulling cable.
4. There should always be adequate personnel in commu-

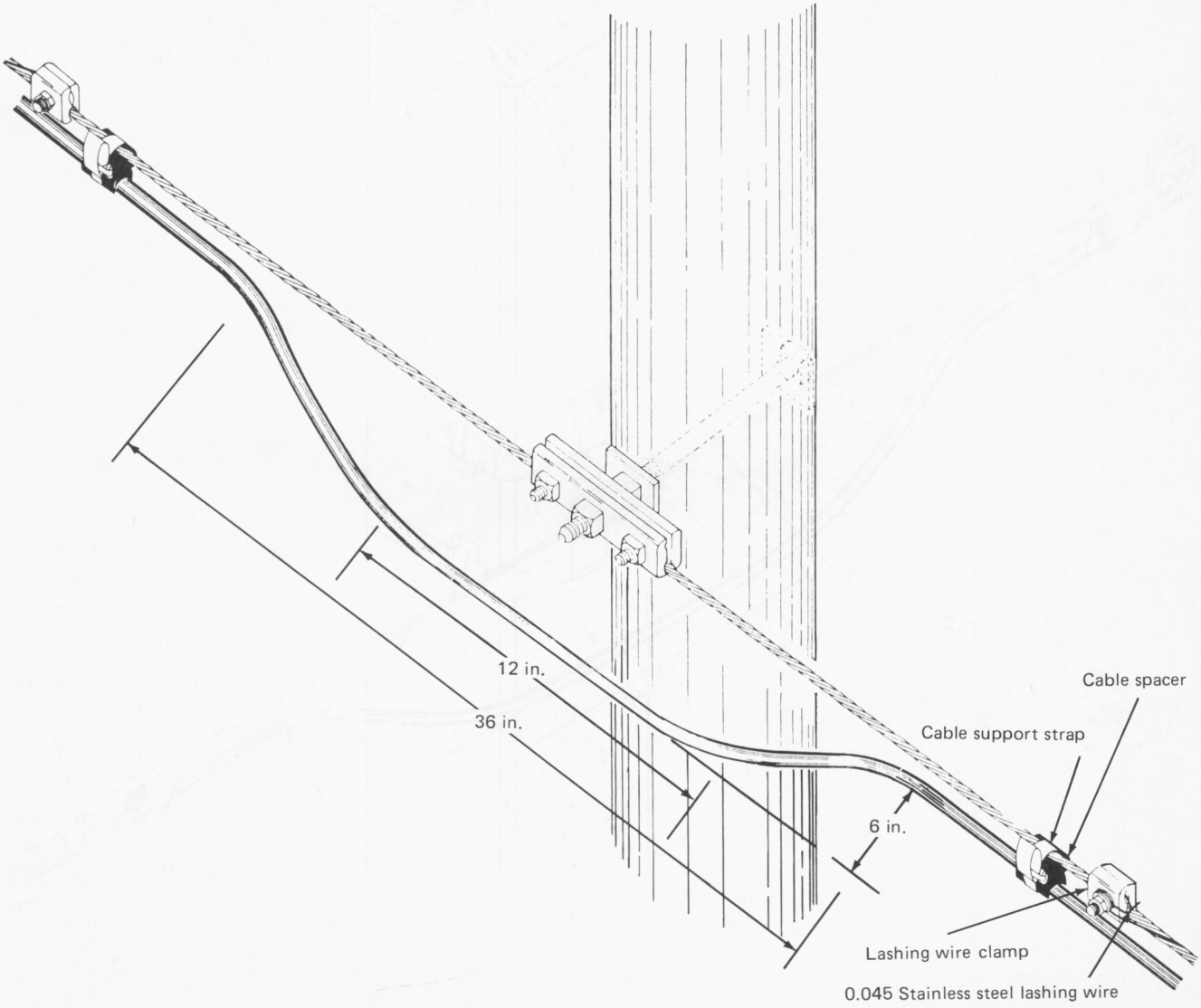


Fig. 12-27. Cable placing—straight line.

nication with the winch operator to watch the cable as it is being pulled into place. After the cable has been pulled into place, the lashing machine, cable block pushers, and the cable positioner are placed on the strand and the coaxial cable properly positioned through them. The cable(s) is (are) then lashed span by span back to the reel trailer location. As each span is lashed, excess cable slack is rerolled onto the reels and all cable blocks removed. The cable at each of the pole locations is attached as shown in Figs. 12-27 to 12-36.

Lashing Wire Precautions

When attaching the lashing wire to the lashing wire clamps, wrap the lashing wire two or three turns around the strand (8 to 10 in. from the clamp) before feeding it through the washers for attachment. To avoid snapping the lashing wire, do not allow it to overlap itself. The tail should be cut off and tucked back into the clamp for future ease of removal. This allows the cable to move within the lashing wire during contraction and expansion and will protect the lashing wire from breakage. The proper procedure is illustrated in Fig. 12-37.

Figure 12-38 shows a cable band and spacer that can be used on single, dual, and triple cable installations. Bands and spacers should not be drawn down too tightly on the cable and strand. The function of bands and spacers is to cradle the cable and support it away from a metal surface. Separation is its sole purpose, not tension. Sometimes the cable band and spaces are used to maintain unsupported cable in areas where cable cannot be lashed. They should be added only after an expansion loop (see the following

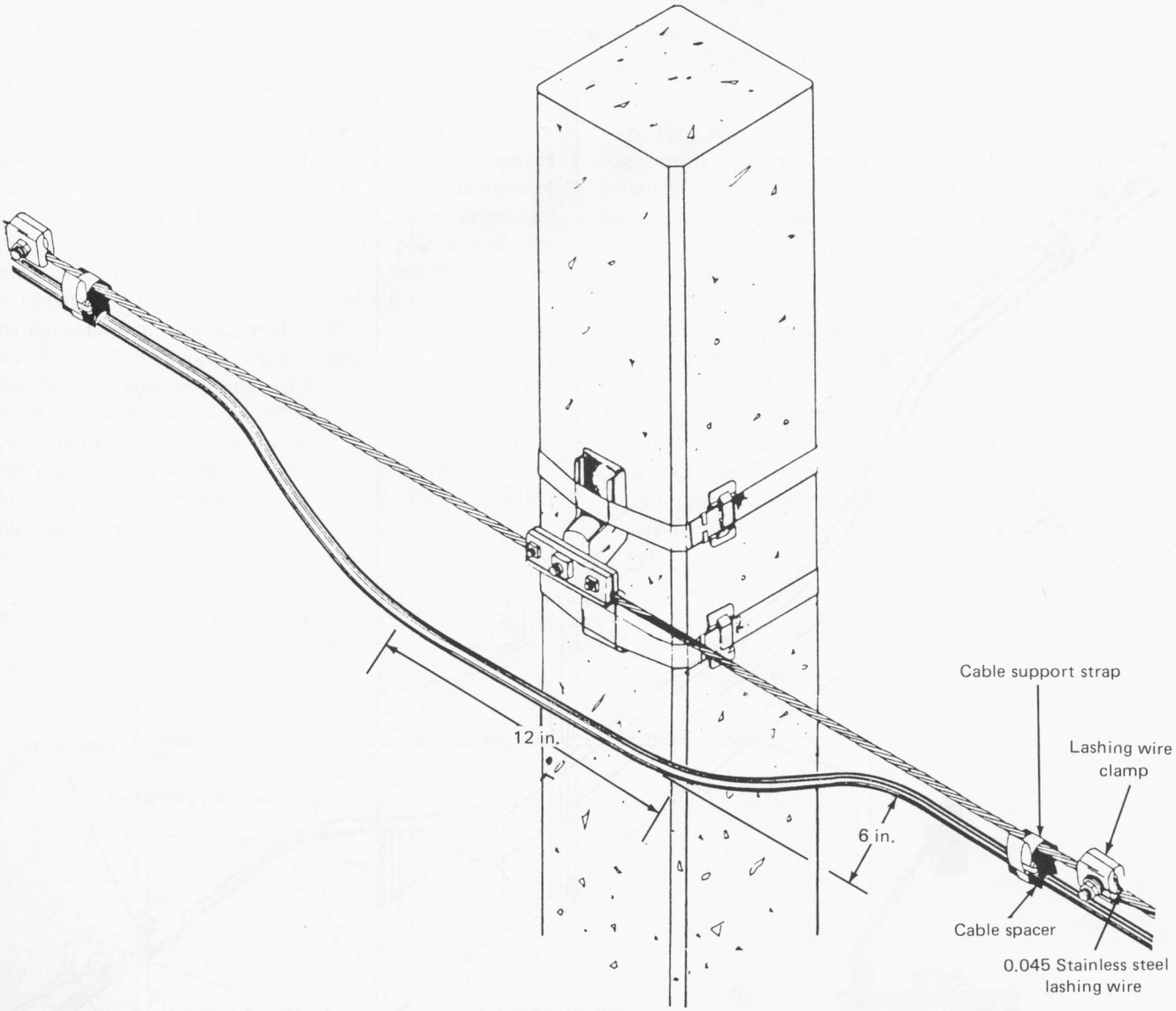


Fig. 12-28. Cable placing—straight line (steel or concrete pole) (*M/A Com Comm-Scope*).

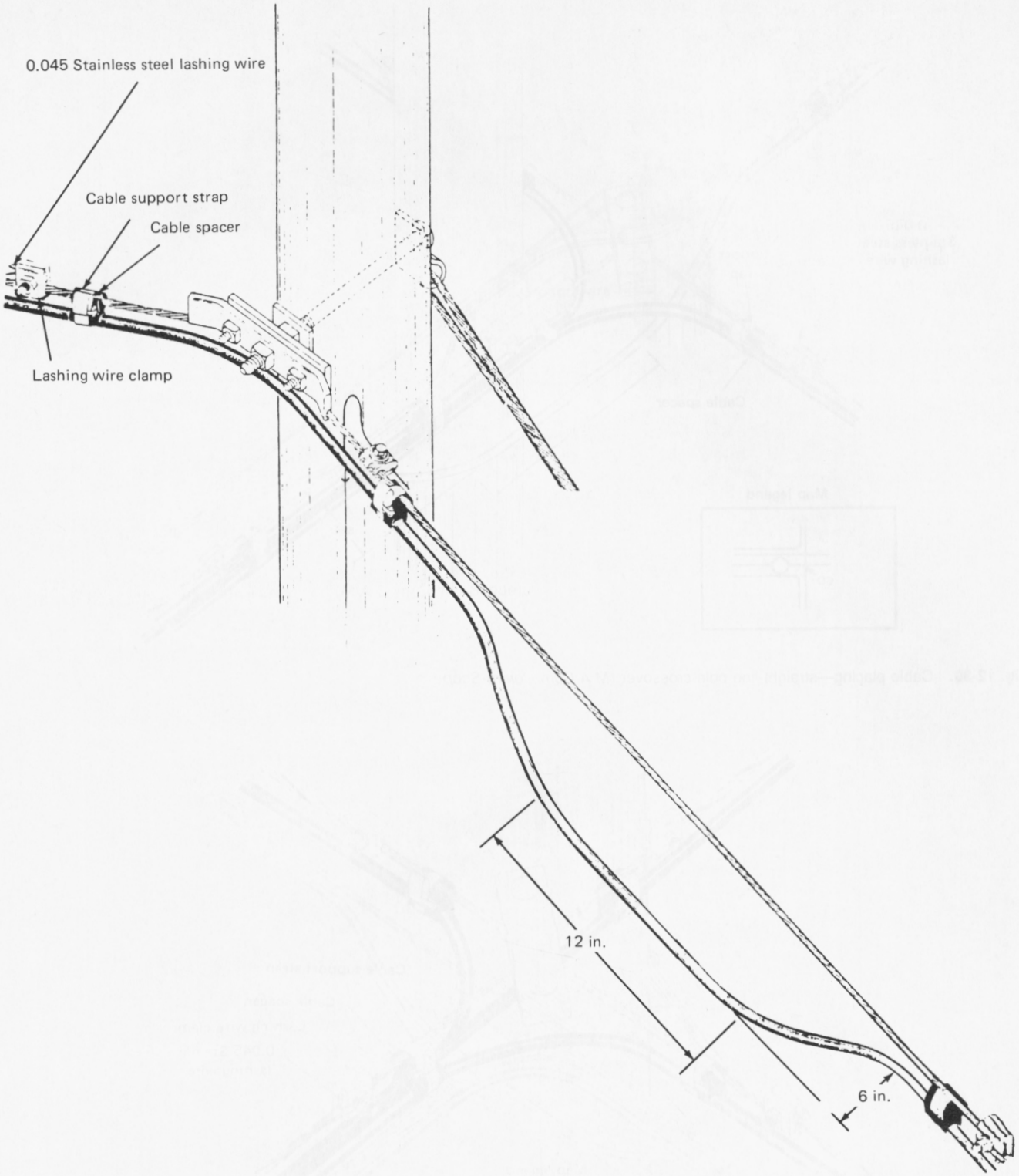


Fig. 12-29. Cable placing—angle post (*M/A Com Comm-Scope*).

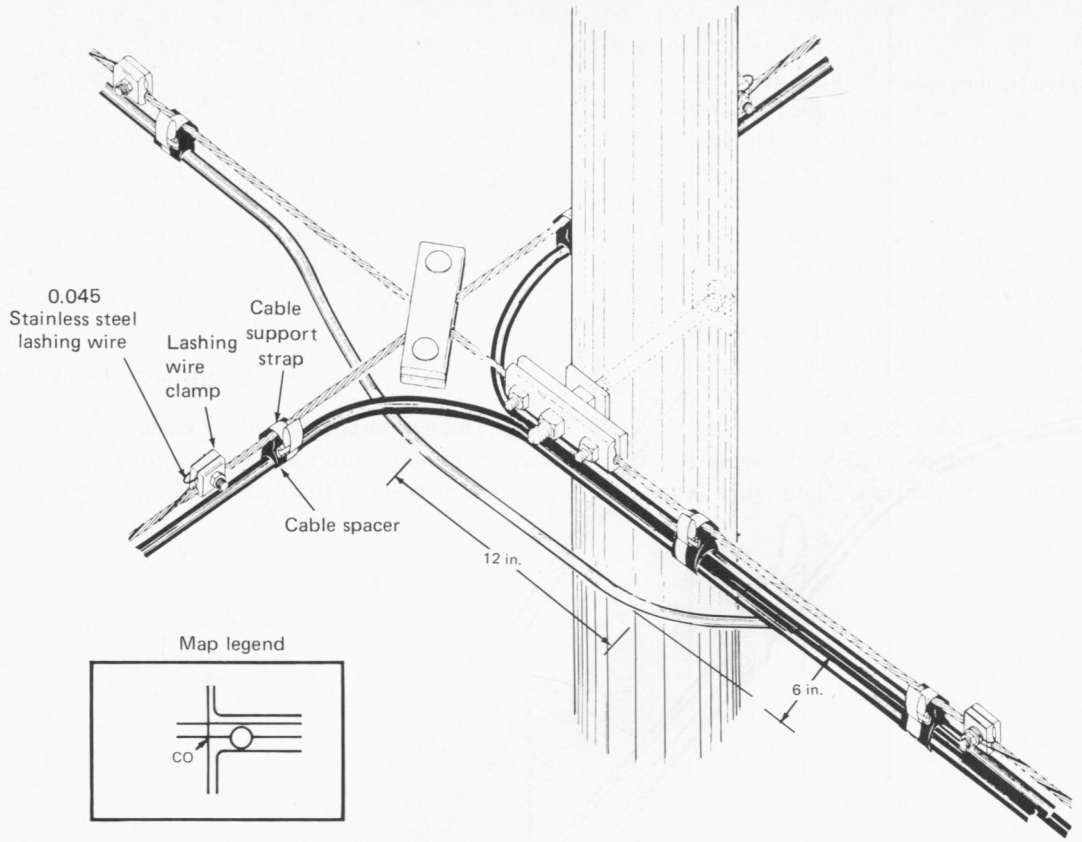


Fig. 12-30. Cable placing—straight-line pole crossover (*M/A Com Comm-Scope*).

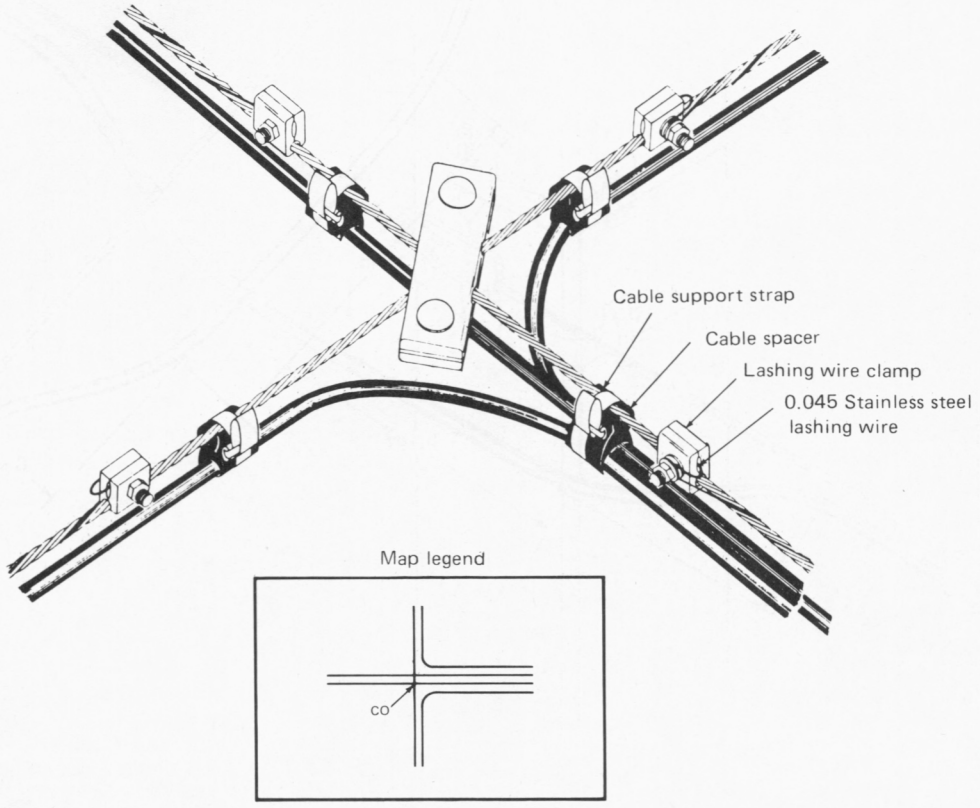


Fig. 12-31. Cable placing—mid-span crossover (*M/A Com Comm-Scope*).

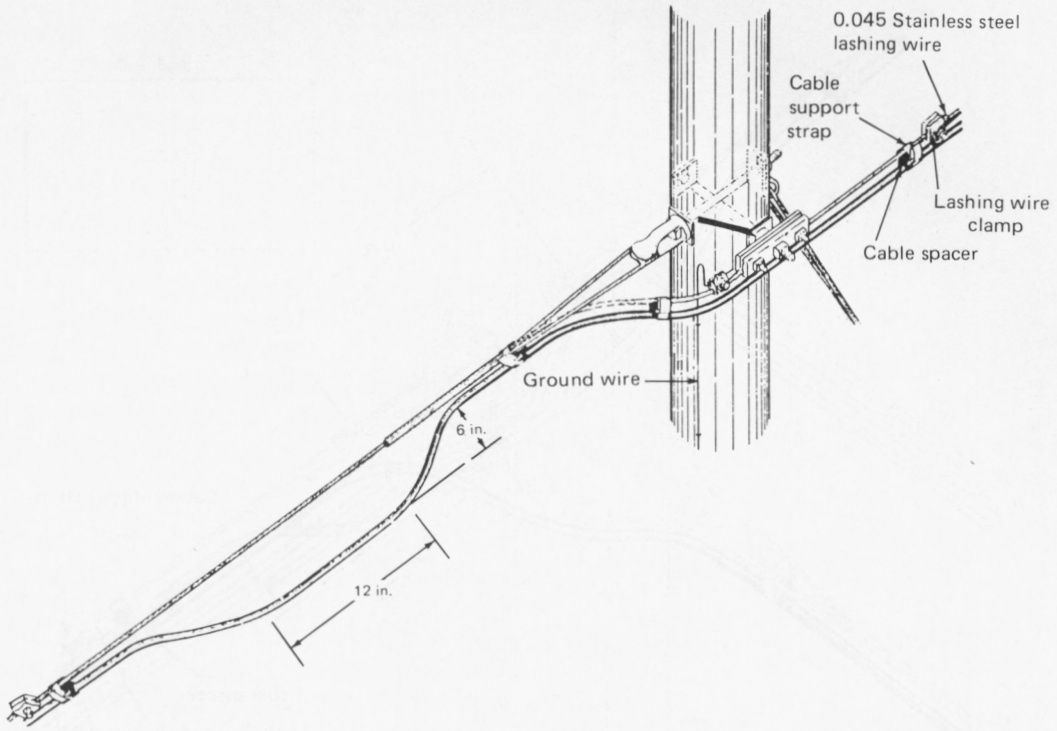


Fig. 12-32. Cable placing—false dead-end (*M/A Com Comm-Scope*).

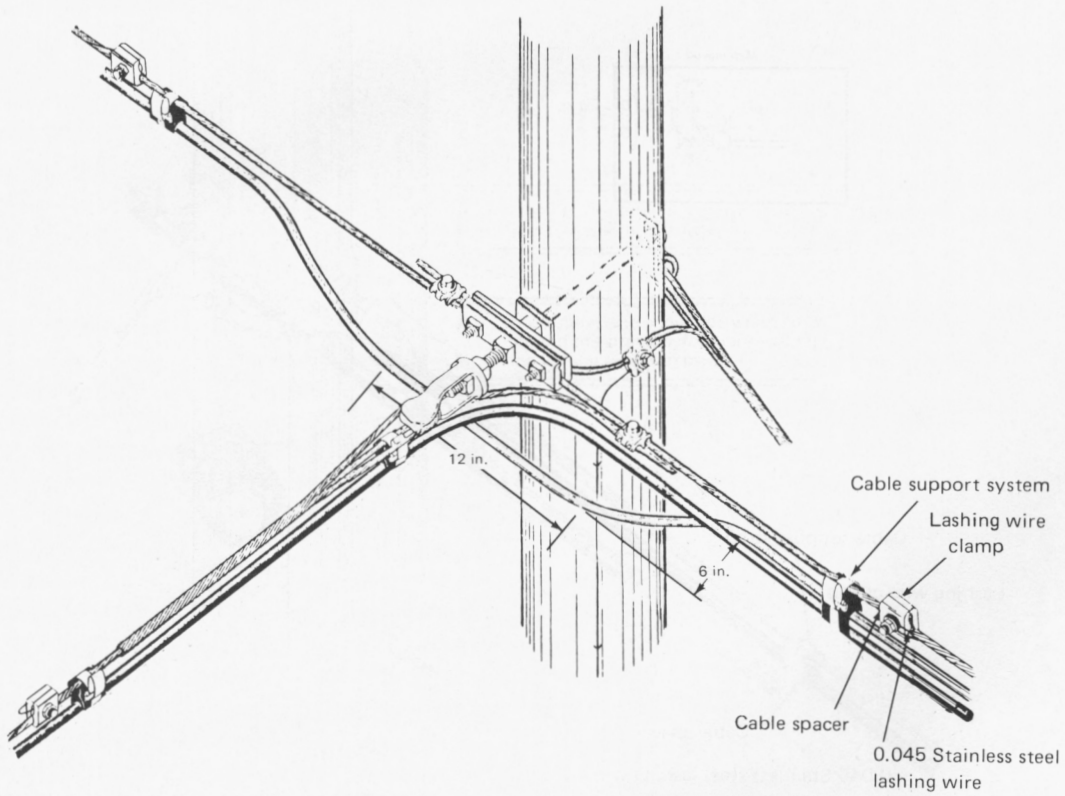


Fig. 12-33. Cable placing—line-pole dead-end combination 1 (*M/A Com Comm-Scope*).

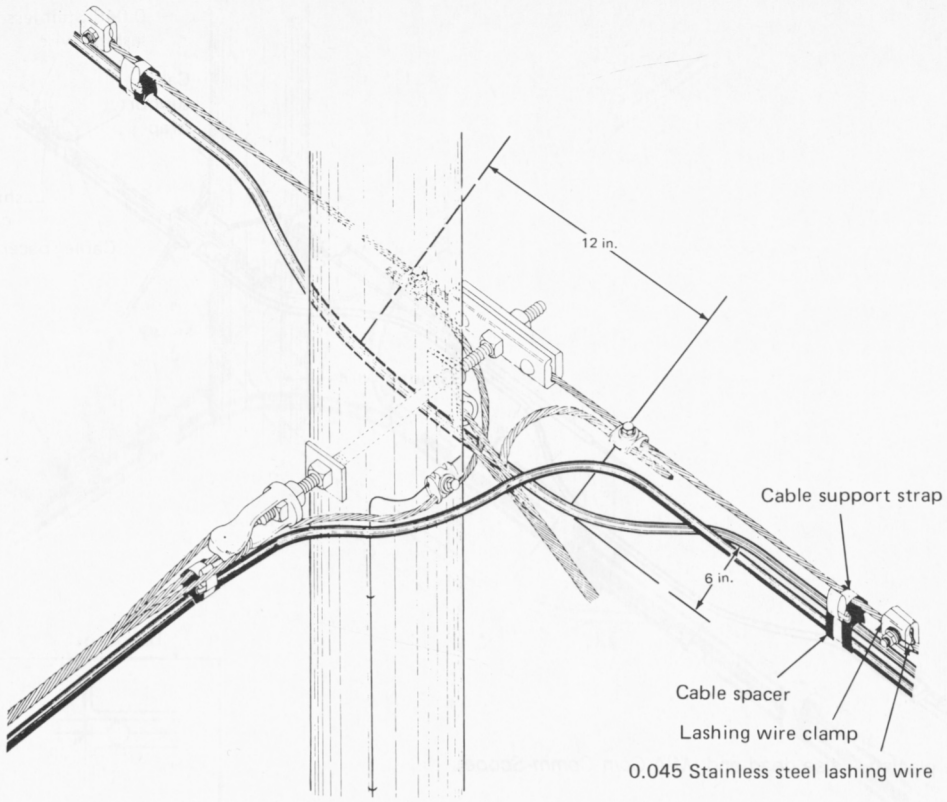


Fig. 12-34. Cable placing—line-pole dead-end combination 2 (*M/A Com Comm-Scope*).

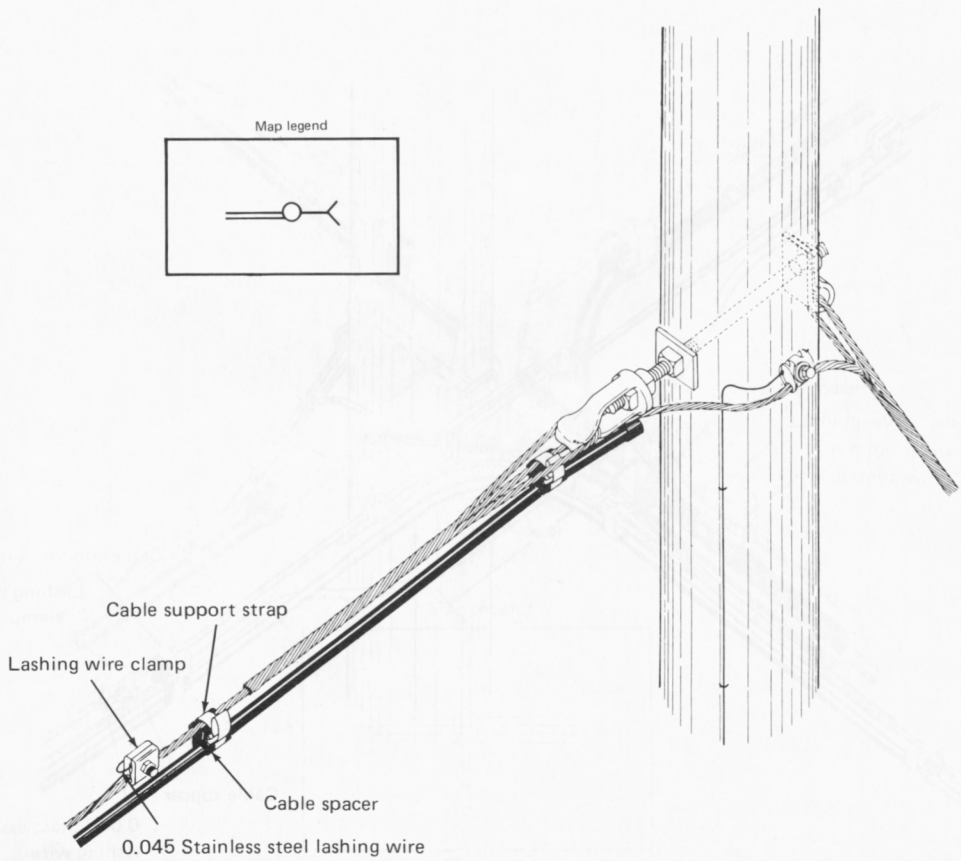


Fig. 12-35. Cable placing—dead-end (*M/A Com Comm-Scope*).

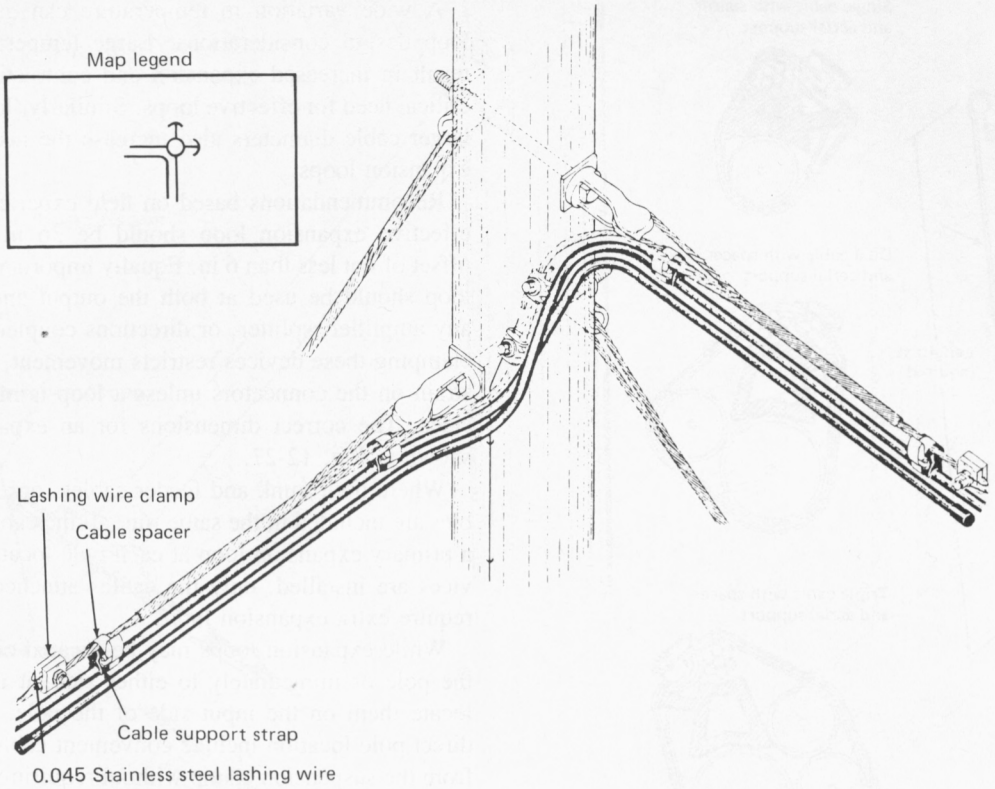


Fig. 12-36. Cable placing—double dead-end (*M/A Com Comm-Scope*).

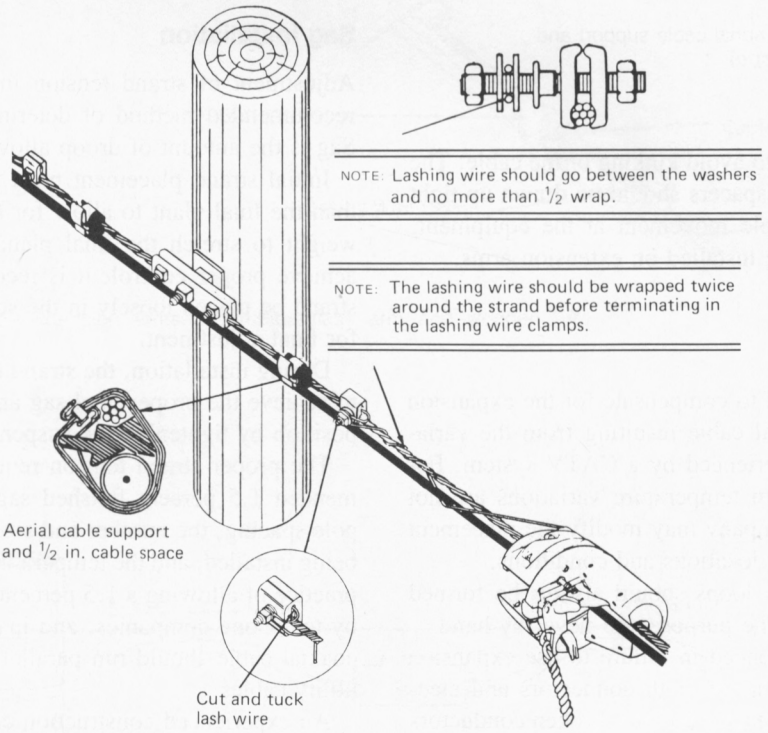
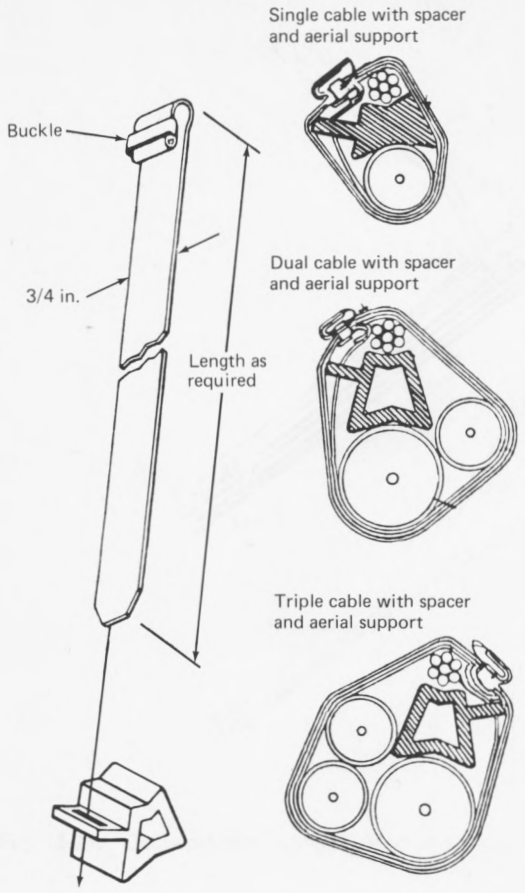

NOTE: Lashing wire should go between the washers and no more than 1/2 wrap.
NOTE: The lashing wire should be wrapped twice around the strand before terminating in the lashing wire clamps.
Aerial cable support and 1/2 in. cable space
Cut and tuck lash wire

Fig. 12-37. Cable placing—lashing wire clamp, aerial support, and spacer (*M/A Com Comm-Scope*).



NOTE:
Wrap the aerial support around the strand and cable(s) 2 or 3 times. Pull each wrap tight, then fold the support under itself, passing it through the buckle, then fold back over the buckle.

Fig. 12-38. Cable placing—aerial cable support and spacer (*M/A Com Comm-Scope*).

section) is made in order to avoid kinking of the cable. The only time that bands and spacers should be drawn up tight is during isolation of cable movement at the equipment. Figure 12-39 shows cable installed on extension arms.

EXPANSION LOOPS

Expansion loops are used to compensate for the expansion and contraction of coaxial cable resulting from the variations in temperature experienced by a CATV system. For locations where maximum temperature variations are not anticipated, the cable company may modify the placement of loops based on similar locations and conditions.

In all cases, expansion loops should always be formed with a tool designed for the purpose and never by hand.

Some problems experienced in failure to use expansion loops include severe strains on both connectors and electronic devices, center conductor pullout, broken conductors and housings, intermittent or degraded signal quality, ghosting, and—in extreme cases—complete power failure.

A wide variation in temperature can greatly influence loop design considerations. Large temperature variations result in increased expansion and contraction and a more critical need for effective loops. Similarly, longer spans and larger cable diameters also increase the need for effective expansion loops.

Recommendations based on field experience are that an effective expansion loop should be 36 in. long with an offset of not less than 6 in. Equally important, an expansion loop should be used at both the output and input side of any amplifier, splitter, or directions coupler. The effect of clamping these devices restricts movement, causing severe strain on the connectors unless a loop is installed on both sides. The correct dimensions for an expansion loop are shown in Fig. 12-27.

Where both trunk and feeder cables, or any multiple cables are included in the same run, all the cables should have a primary expansion loop at each pole location. Where devices are installed, only the cables attached to the device require extra expansion loops.

While expansion loops may be located either directly at the pole or immediately to either side, it is customary to locate them on the input side of the pole. Advantages of direct pole location include convenient cable spacing away from the suspension clamp without requiring spacers, physical protection from severe wind and weather conditions, and handling ease if a spacer is used for loop formation.

Figures 12-40 to 12-43 show various expansion loop configurations.

SAG CONTROL AND UNDERGROUND DIPS

Sag Installation

Adjustment of strand tension in the finished plant is the recommended method of determining proper sag control. Sag is the amount of droop allowed in a cable span.

Initial strand placement must always be slightly tighter than the final plant to allow for the installed coaxial cable weight to stretch the final plant into the proper sag. To achieve proper control, it is recommended that the initial strand be placed loosely in the suspension clamps to allow for final adjustment.

During installation, the strand tension should be adjusted to achieve the proper final sag and then held in the correct position by tightening the suspension clamps.

The proper strand tension required to achieve a recommended 1.5 percent finished sag at 70°F depends on the pole spacing, the number and size of trunk or feeder cables being installed, and the temperature at installation time. The practice of allowing a 1.5 percent sag is generally followed by telephone companies, and in most cases the sag of the coaxial cable should run parallel with the sag of the other utility cables.

An experienced construction crew will normally be able to determine the proper sag without directly measuring strand tension. It is also possible to directly calculate the actual

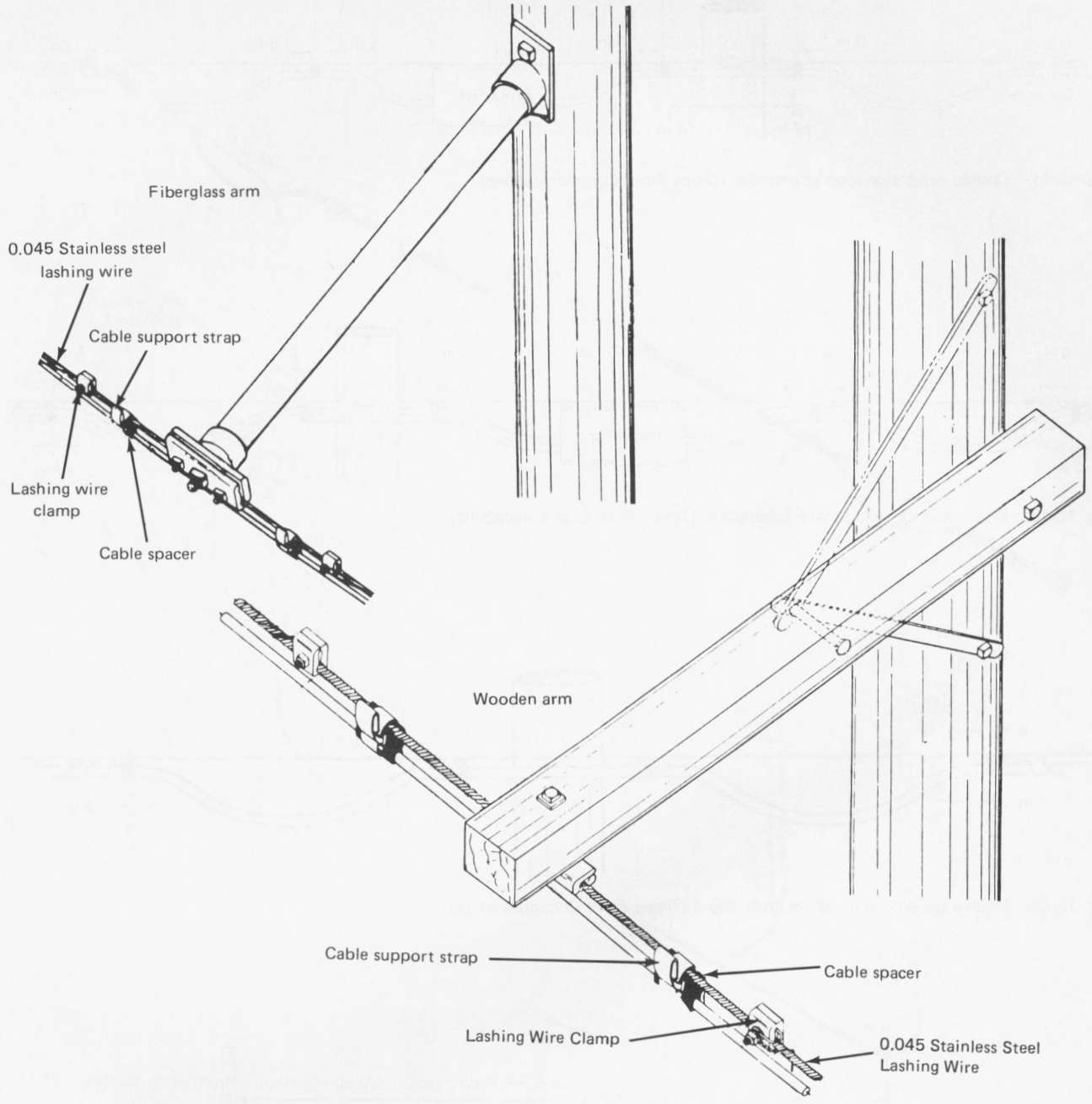


Fig. 12-39. Cable placing—extension arms. Both Fiberglass arm and wooden arm (*M/A Com Comm-Scope*).

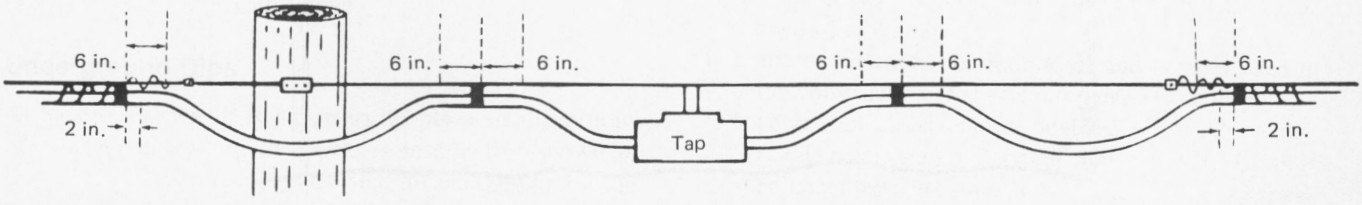


Fig. 12-40. Double expansion loop at tap (*Times Fiber Communications*).

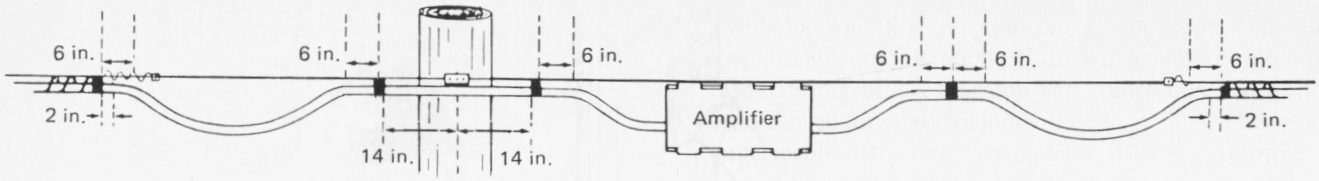


Fig. 12-41. Double expansion loop at amplifier (*Times Fiber Communications*).

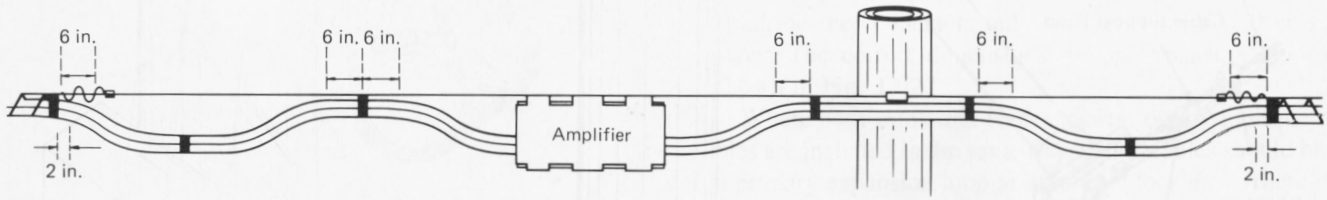


Fig. 12-42. Dual cable expansion loop at amplifier (*Times Fiber Communications*).

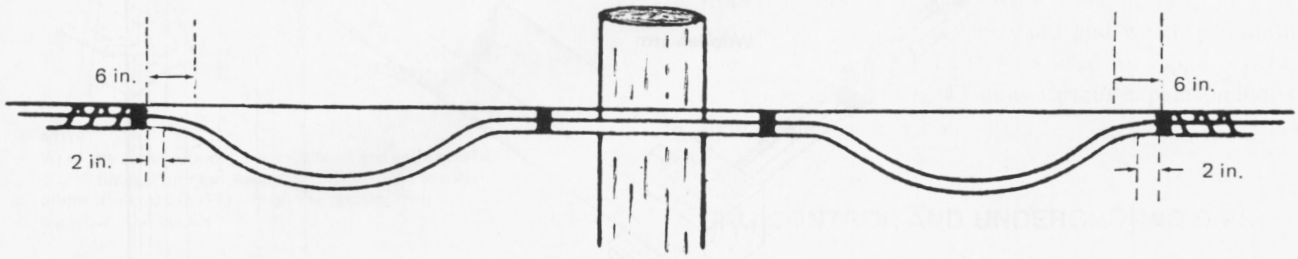


Fig. 12-43. Double expansion for spans over 200 ft (*Times Fiber Communications*).

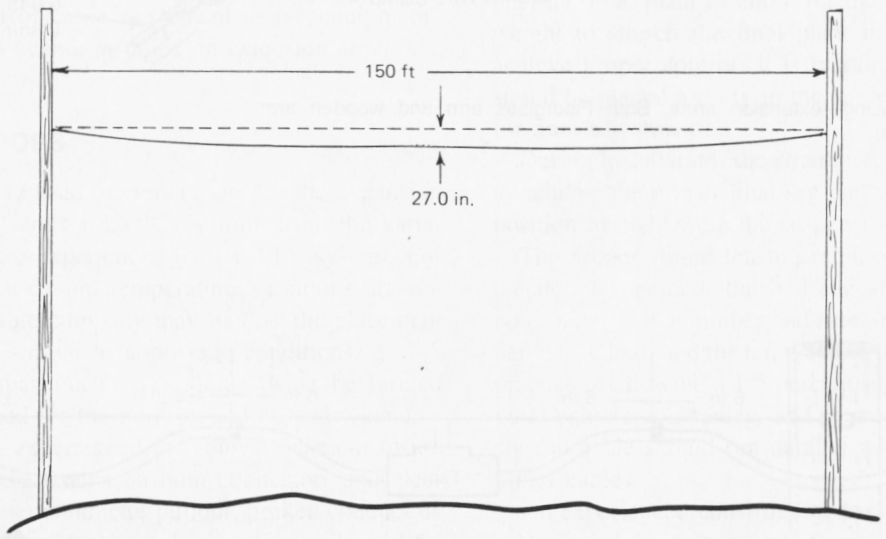


Fig. 12-44. Allowable sag for a 150-ft span.

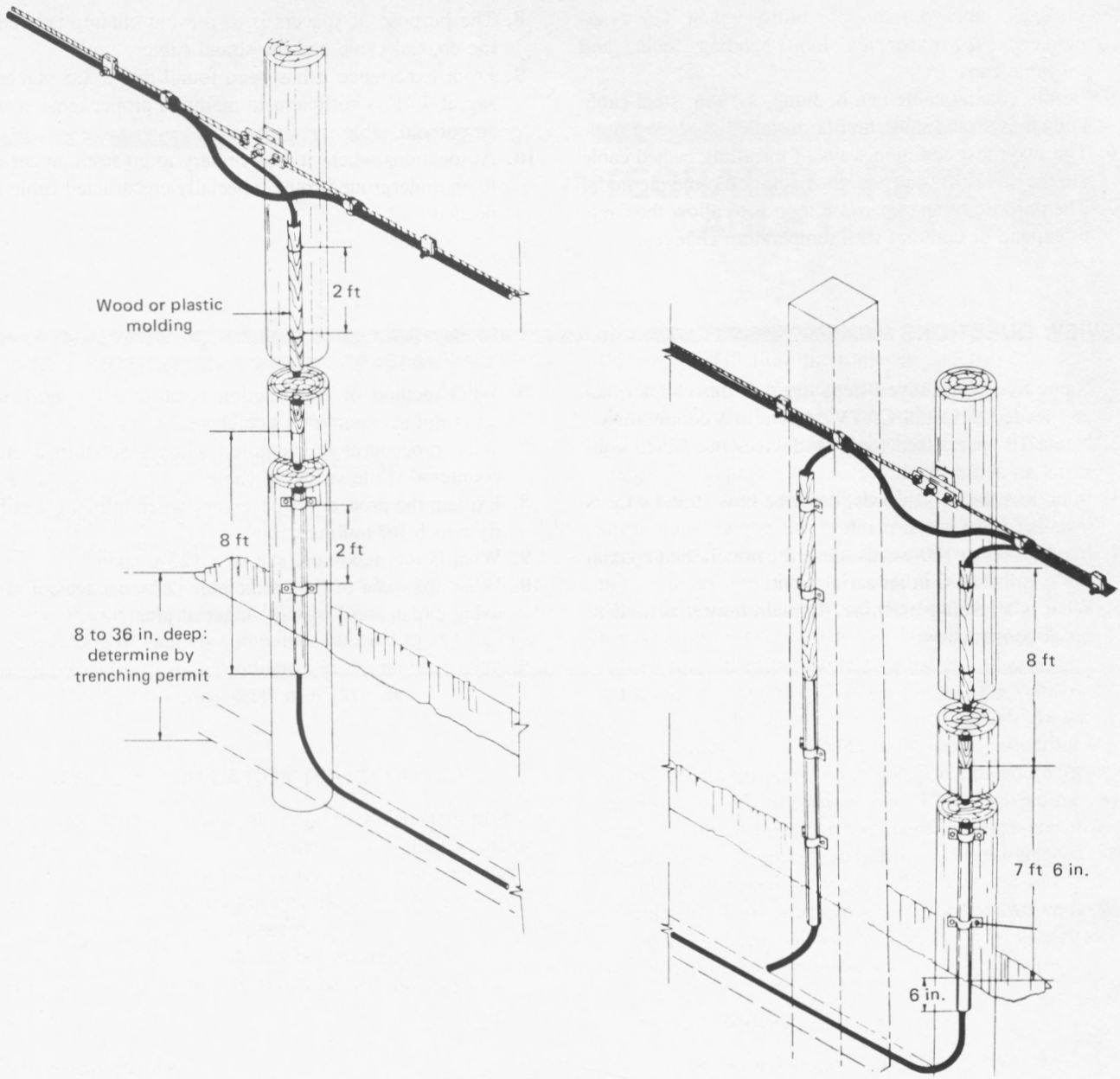


Fig. 12-45. Typical underground dip methods (*M/A Com Comm-Scope*).

sag in a finished plant by measuring strand tension with a strand tension dynamometer.

To determine the sag of a cable, multiply the span distance by 0.015. The result will be the amount of difference between the lowest point at midspan and a line drawn straight between the two poles. Figure 12-44 shows an allowable sag of 27.0 in. on a 150-ft span.

Underground Dips

At locations where it is necessary to place small portions of cable underground, the cable is installed as shown in Fig. 12-45. It is recommended that all underground cable be solid dielectric with jacket and flooding compound. There should never be a break in underground coaxial cable.

SUMMARY

1. The installation of coaxial cable on utility poles is known as aerial construction.
2. Coaxial cable is placed above telephone service and below the electrical power lines.
3. The process of making space available for CATV is known as make ready.
4. Some of the more common tools and devices used in aerial construction are (*a*) reel trailers, (*b*) cable guides, (*c*) corner block attachment devices, (*d*) corner blocks, (*e*) cable positioners, (*f*) strand chute brackets, (*g*) pole attachment brackets, (*h*) single and multiple cable pullers, (*g*) cable blocks, (*h*) cable block rods, (*i*) cable lifter heads, (*j*) lashing machines, (*m*) catch-off clamps,

(*n*) cable block pushers, (*o*) utility winch, (*p*) dynamometer, (*q*) expansion loop bending tools, and (*r*) cable caps.

5. Before coaxial cable can be hung, a ¼-in. steel cable known as strand must first be installed.
6. The two most common ways of installing lashed cable are the drive-off route and the back-pull route methods.
7. The purpose of an expansion loop is to allow the cable to expand or contract with temperature changes.
8. The purpose of spacers is to prevent chafing between the coaxial cable and the strand cable.
9. From experience it has been found that a 1.5 percent sag at 70°F is sufficient to maintain proper tension on strand and cable.
10. At locations where it is necessary to go from an aerial to an underground route, specially constructed cable is needed.

REVIEW QUESTIONS

1. Name five of the seven steps listed in this chapter that are needed to install CATV service in a community.
2. Name 10 specialized tools or devices needed to construct an aerial plant.
3. In no less than 100 words, describe how strand wire is installed in an aerial plant.
4. In no less than 100 words, describe how lashed coaxial cable is installed in an aerial plant.
5. What is a lashing machine? Explain how it is used in aerial construction.
6. What method of construction is utilized for work in areas not accessible by vehicles?
7. What procedures are required when a 50° turn is encountered while stringing cable?
8. Explain the procedures necessary when utilizing a utility winch for pulling cable.
9. What is the maximum sag of a 125-ft span?
10. What are some of the predictable consequences of not using expansion loops in an aerial plant?

13 CHAPTER

INTEGRATED MESSENGERED CABLE CONSTRUCTION

INTRODUCTION

In this chapter you will learn about:

1. The installation of integrated messengered cable
2. Cable splicing techniques
3. Ground helpers' responsibilities
4. Construction codes

Integrated messenger cable is coaxial cable that has a strand cable already incorporated into the jacket. Integrated messengered (IM) cable is sometimes referred to as "figure-8" cable because of its resemblance to the number eight. Figure 13-1 shows a cross section of IM cable.

IM CABLE INSTALLATION PROCEDURES

The installation of IM cable is quite different from that of lashed cable, and attention to maximum sag and tension is very important. The effects of tension and temperature can be reduced significantly through the use of expansion loops and captive conductor connectors.

Just as with lashed cable, when stringing IM cable there are some routes considered as drive-off and others considered as back-pull.

Drive-off Route

On drive-off routes the cable will play out directly onto the pole where it is to be attached. In the drive-off method of IM cable installation, the trailer is parked 50 ft beyond the first pole and the appropriate safety equipment is placed along the route. The hardware is then attached to the poles and cable block rods, and cable blocks are placed into the suspension clamps.

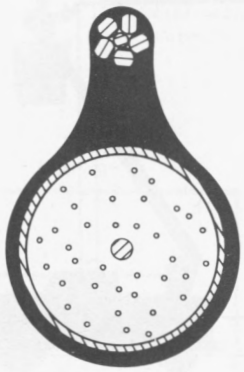


Fig. 13-1. Integrated messengered (figure-8 configuration) coaxial cable.

If J hooks are used, rods and blocks are required only at stress points along the route. When all the hardware and equipment are in place, the crew then secures the IM cable in the suspension clamp of the first pole. The vehicle then pulls the reel trailer beyond the second pole, stops, and backs up to relieve the tension. Using a layup stick with a cable lifting head the cable is lifted and placed into either a J hook or cable block. When placed, the vehicle moves to the next pole and the process is repeated. As the cable is being strung, crew members are loosely securing the IM strand into the suspension clamps. The procedure for stringing IM cables is shown in Fig. 13-2. Depending on the requirements of the system, expansion loops are installed, the cable sagged, and the suspension clamps tightened. When a reel ends, the ends of both the new and old reels are overlapped 30 in. and capped. After the two ends of the strand have been spliced by means of a strandlink, the stringing process continues.

Back-Pull Routes

Again, a back-pull route is required when cable is to be strung over easements, existing facilities, or areas inaccessible to vehicles. Once the appropriate pieces of safety equipment are placed along the proposed route, installation of the cable begins.

In the back-pull method of IM cable installation, the trailer is disconnected from the vehicle, placed about 50 ft from the first pole, and the wheel chocks are set. The hardware is placed and the cable block rods and cable blocks are installed into the suspension clamps. A rotating-eye pulling grip is placed on the strand of the cable and a pulling line attached. The pulling line is placed in a 45° corner block or cable chute and attached to the vehicle. Figure 13-3 shows the procedure for pulling IM cable utilizing the back-pull method. As the IM cable is pulled at locations that require a bend, 45 and 90° corner blocks are utilized. Figure 13-4 illustrates the procedures used in making a bend with IM coaxial cable.

As the IM cable crosses an intersection, caution must be

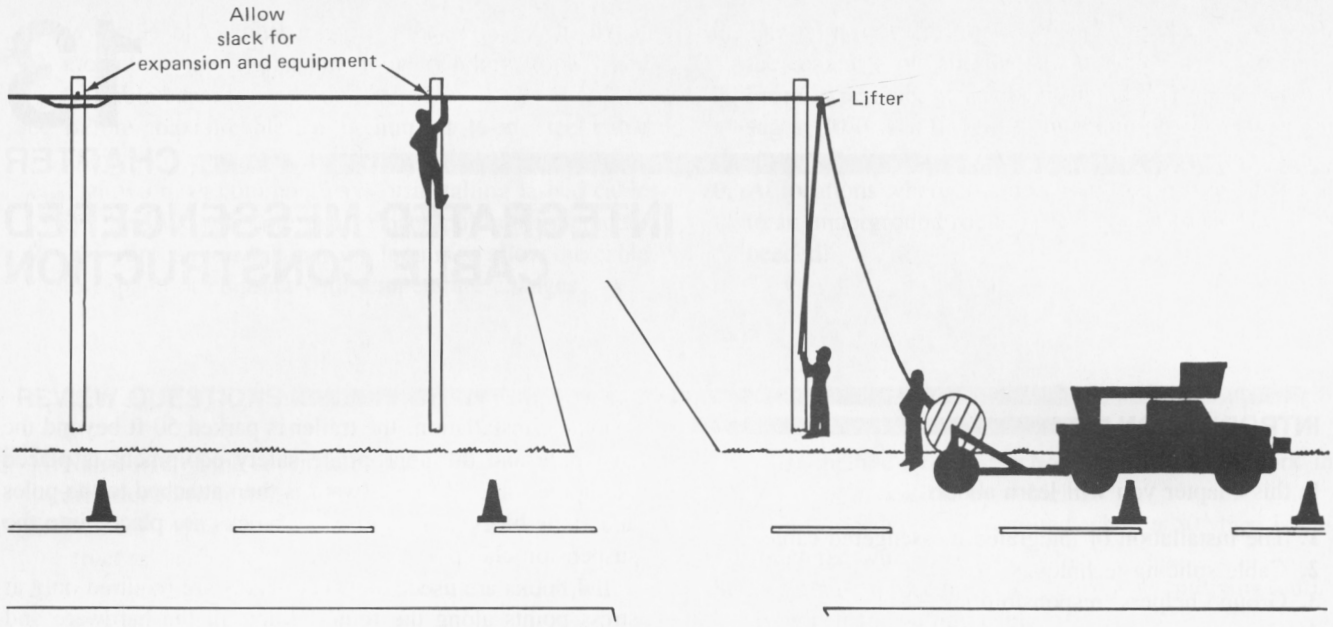


Fig. 13-2. Drive-off route of installing IM coaxial cable (*M/A Com Comm-Scope*).

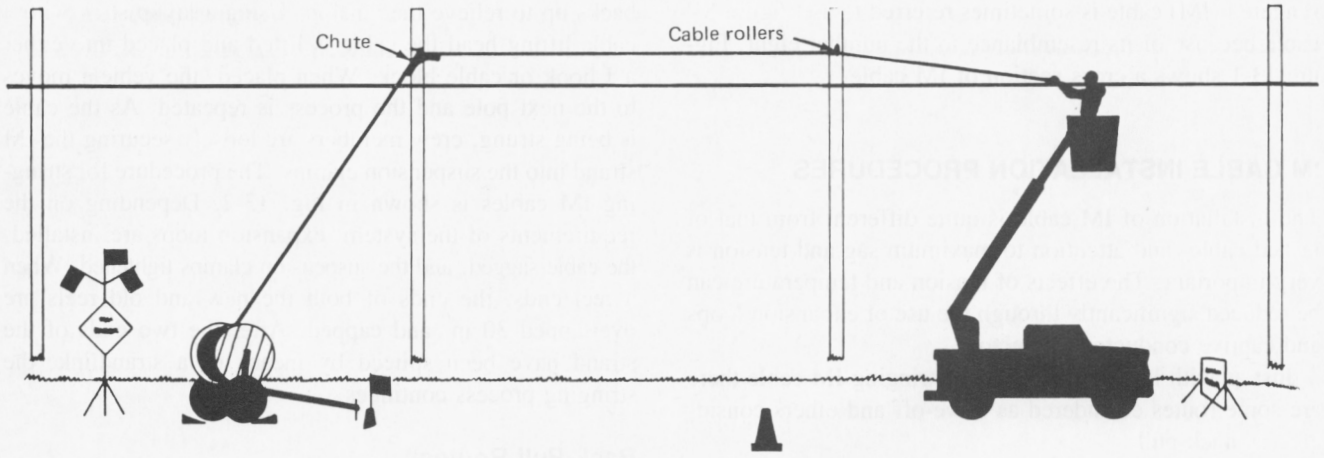


Fig. 13-3. Back-pull route method of installing IM coaxial cable (*M/A Com Comm-Scope*).

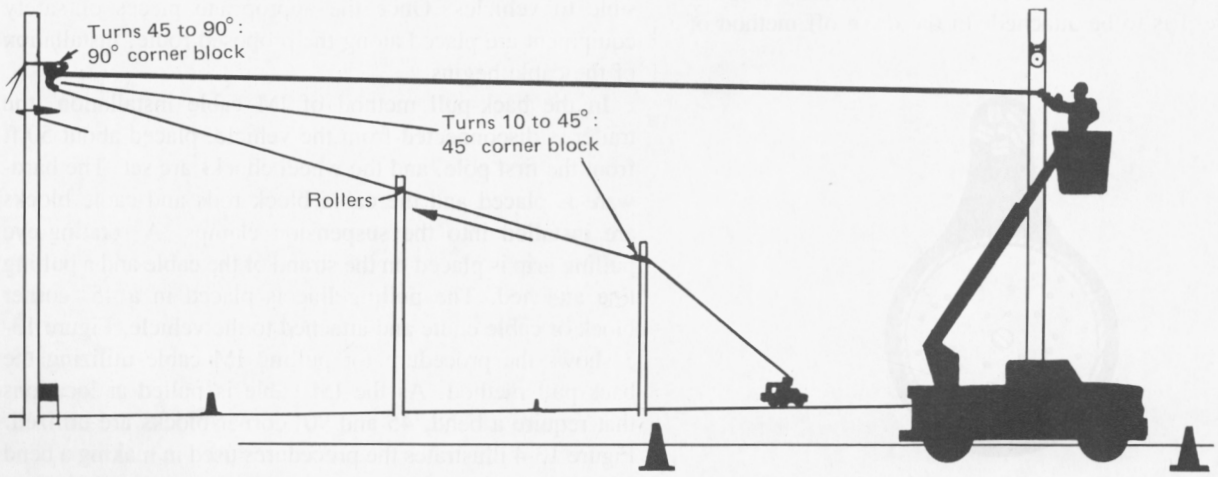


Fig. 13-4. Making a bend with IM coaxial cable (*M/A Com Comm-Scope*).

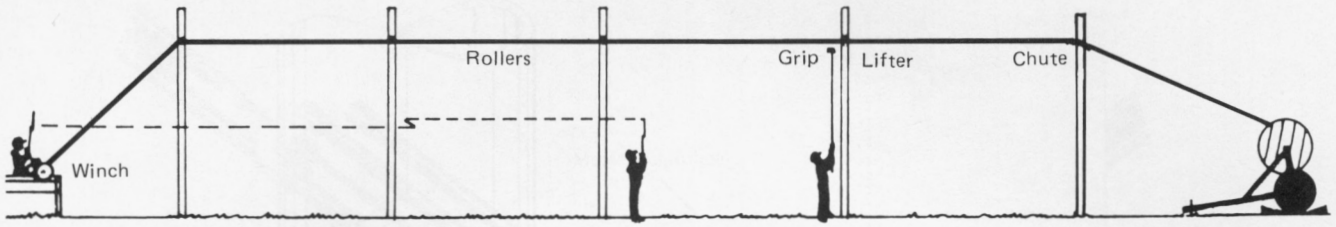


Fig. 13-5. Back-pull winch method of IM cable installation (*M/A Com Comm-Scope*).

taken not to impede traffic with low-hanging cable. The same procedures regarding expansion loops, cable caps, and 30 in. of overlap at the ends of reels apply as before.

Back-Pull–Winch

If conditions warrant, a winch may be employed to pull the IM cable in areas inaccessible to vehicles. In the back-pull–winch method, the trailer is placed 50 ft behind the beginning of the cable run. All hardware, cable blocks, cable block rods, down guys, chutes, anchors, and bonds are placed on the first pole. A pulling eye is installed on the strand of the cable, and a line is run to the winch. As the cable is pulled, the various pieces of equipment are removed and the strand is placed loosely in the suspension clamps. When the expansion loops are formed and the proper sag achieved, the strand is secured by tightening the suspension clamps. On long cable pulls, a dynamometer is used to ensure proper tension. When winching operations are in progress, there should be adequate communication between the winch operator and the construction crew to provide for a safe installation. Figure 13-5 shows the back-pull–winch method used for cable installations. Figures 13-6 to 13-15 illustrate IM cable installed on poles.

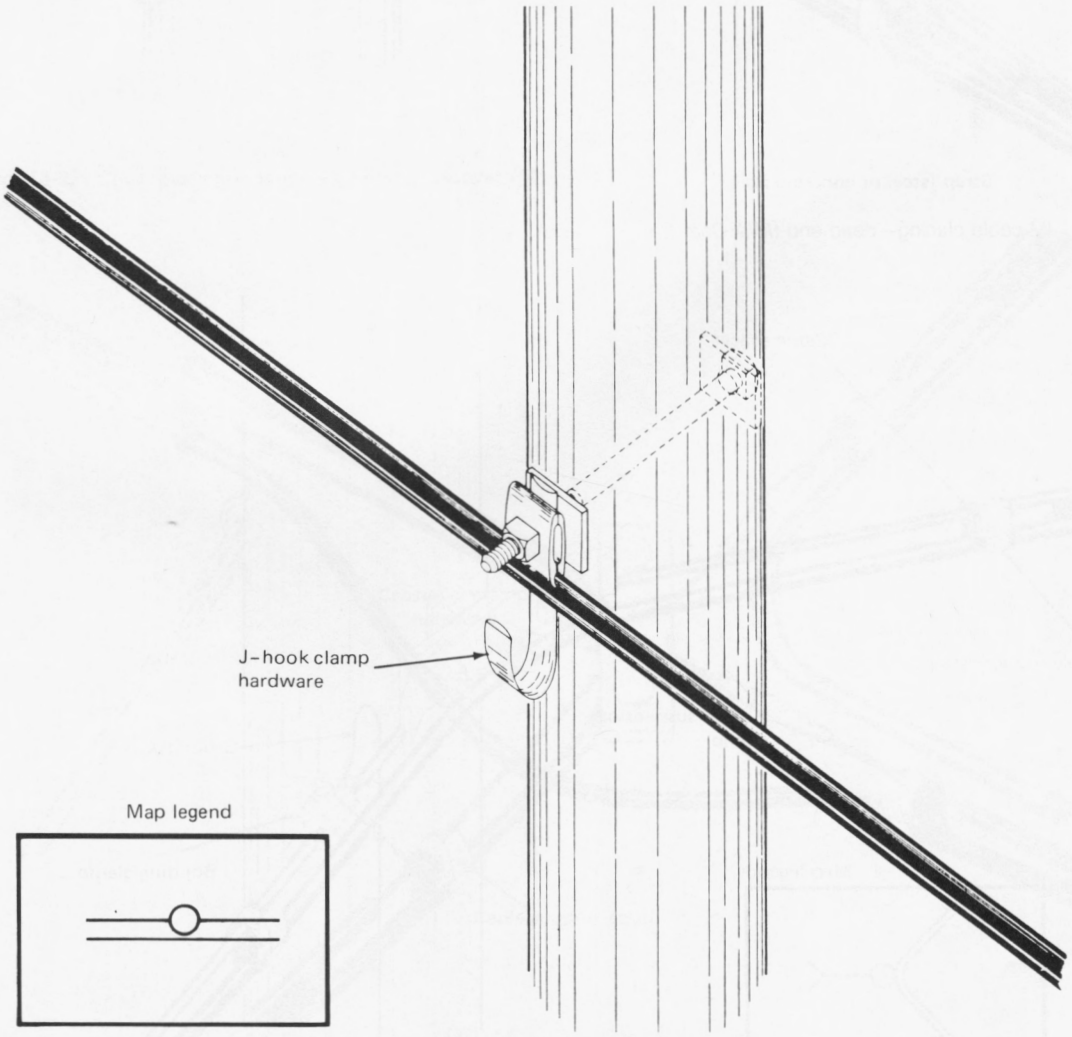


Fig. 13-6. IM Cable placing—straight line (*M/A Com Comm-Scope*).

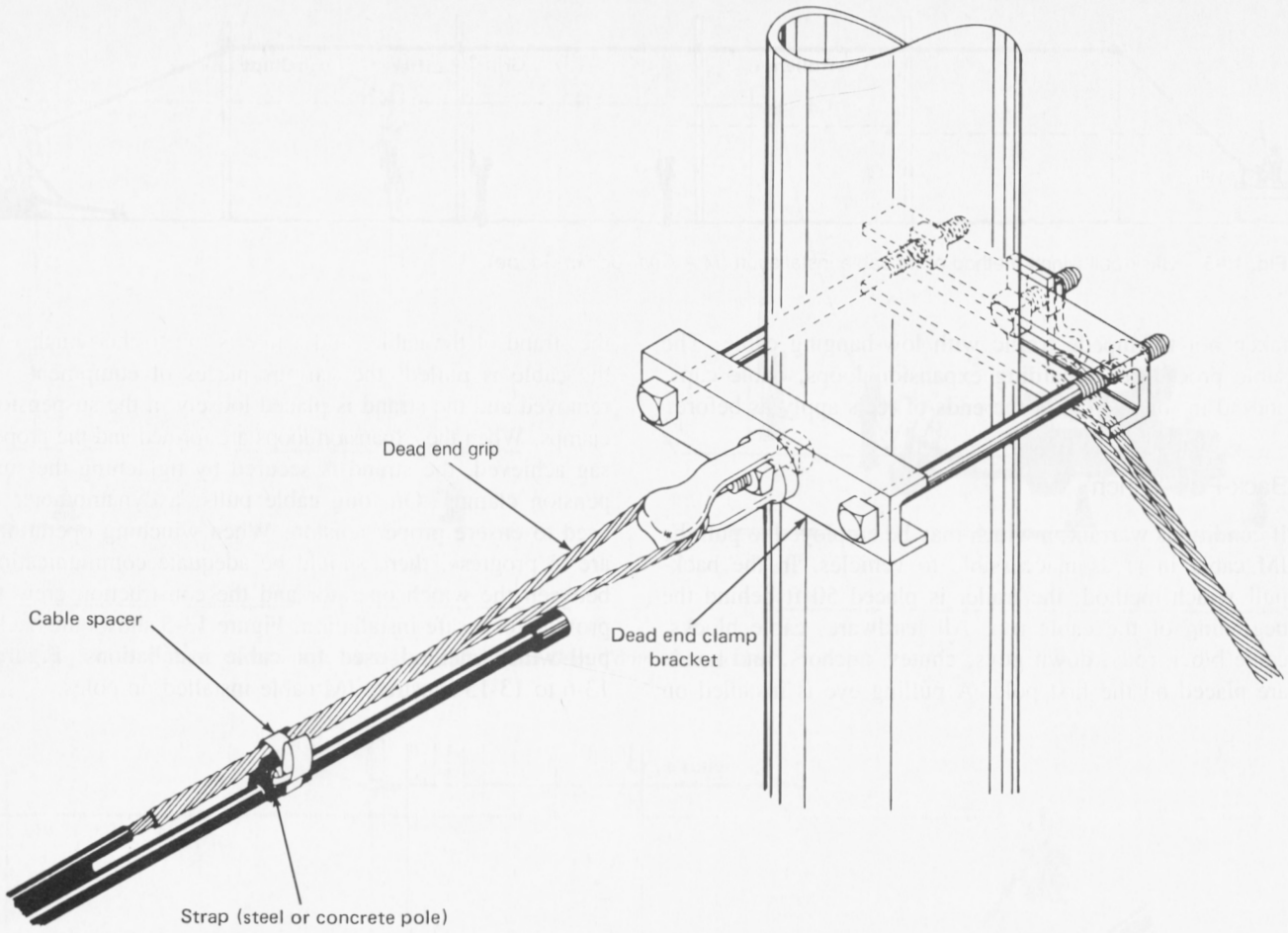


Fig. 13-7. IM cable placing—dead-end (*M/A Com Comm-Scope*).

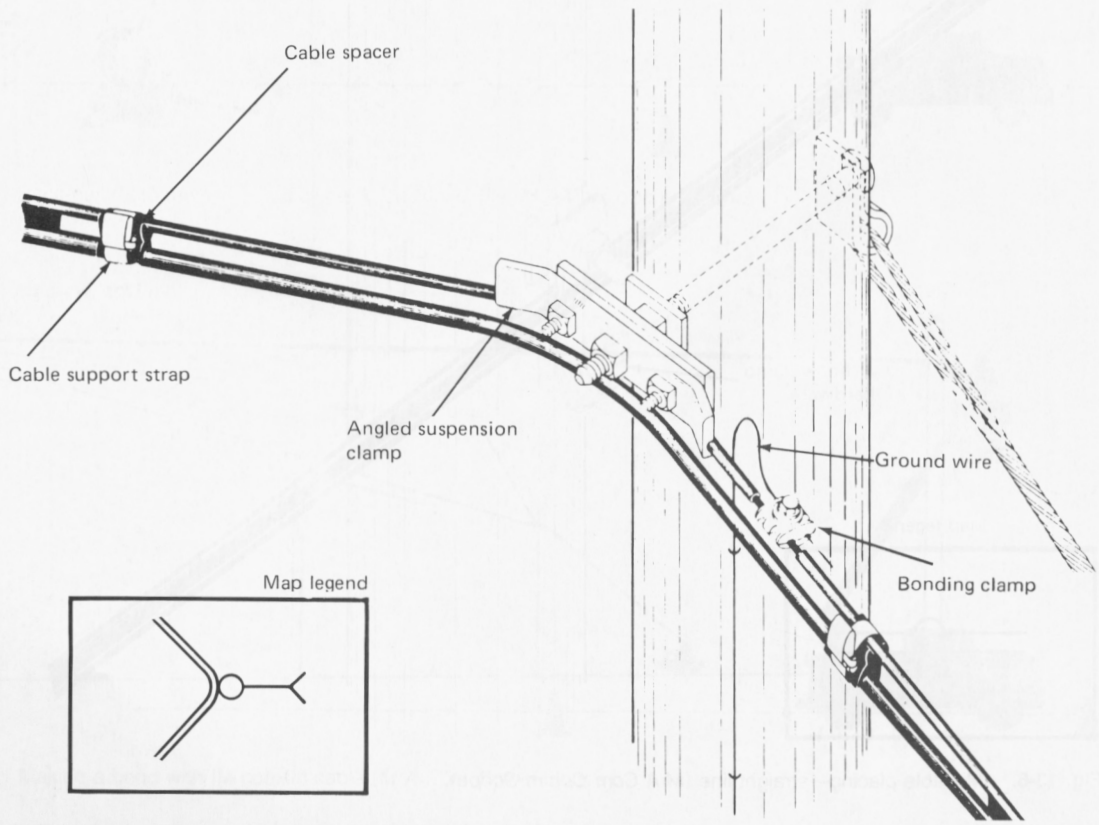


Fig. 13-8. Cable placing—angle pole (*M/A Com Comm-Scope*).

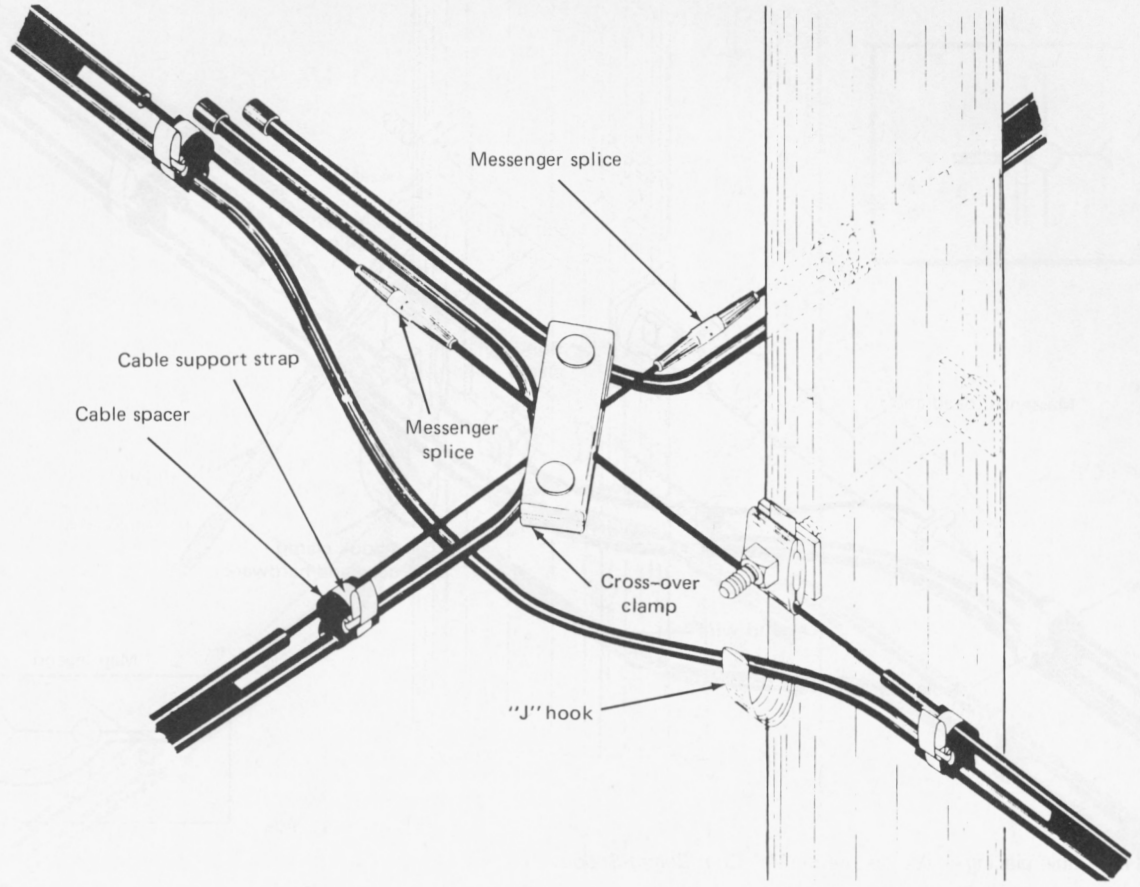


Fig. 13-9. Cable placing—straight-line pole crossover (*M/A Com Comm-Scope*).

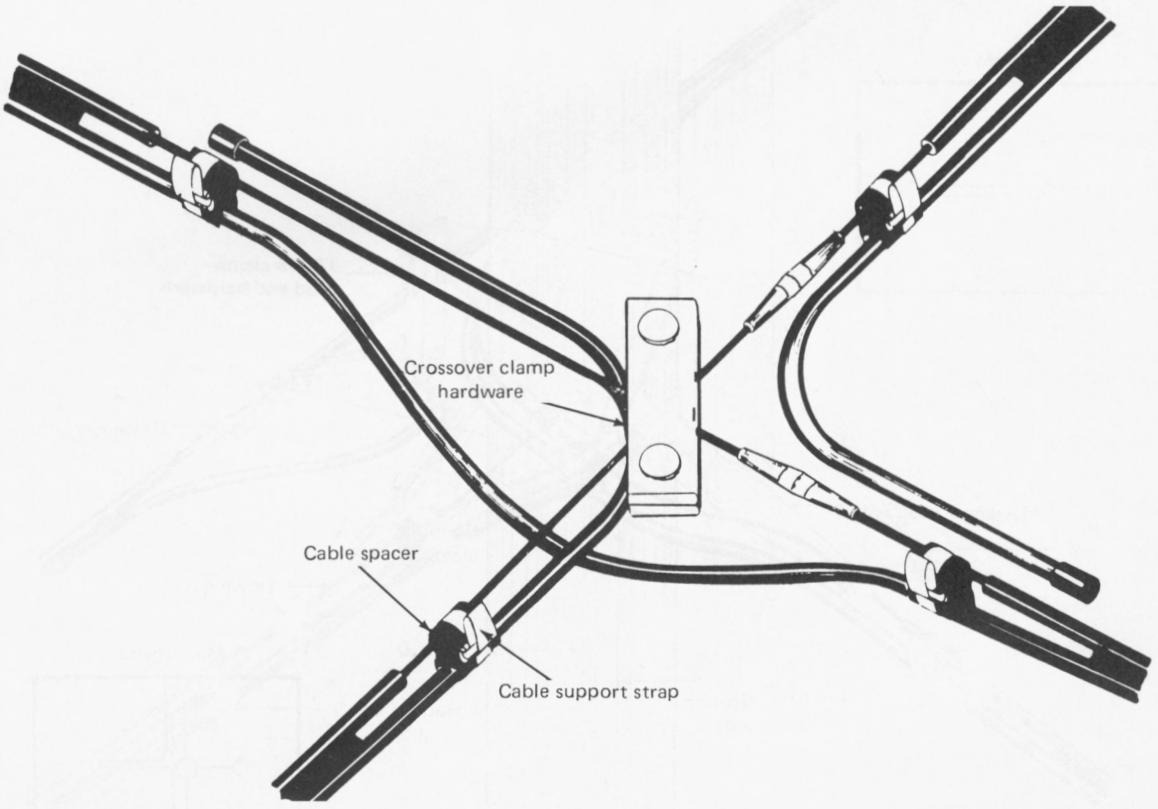


Fig. 13-10. Cable placing—midspan crossover (*M/A Com Comm-Scope*).

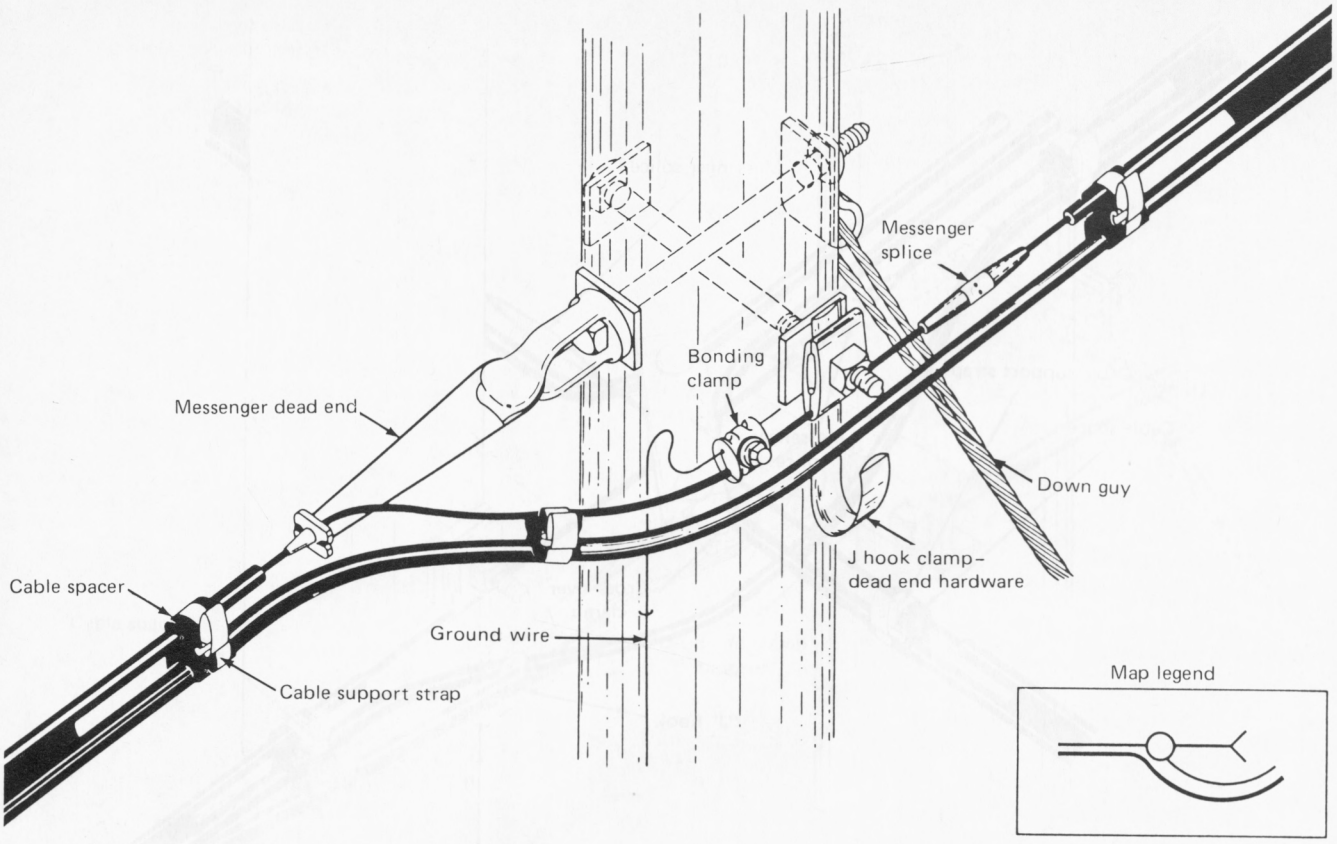


Fig. 13-11. Cable placing—false dead-end (*M/A Com Comm-Scope*).

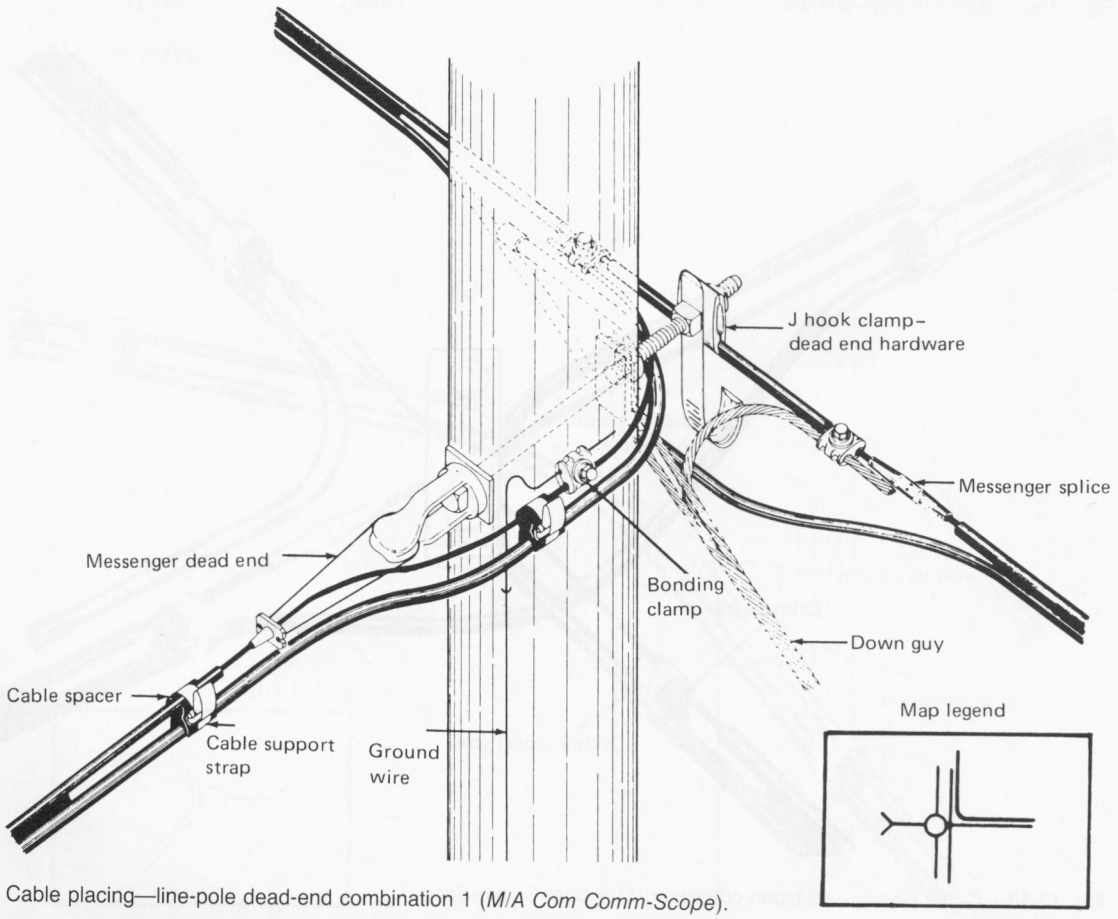


Fig. 13-12. Cable placing—line-pole dead-end combination 1 (*M/A Com Comm-Scope*).

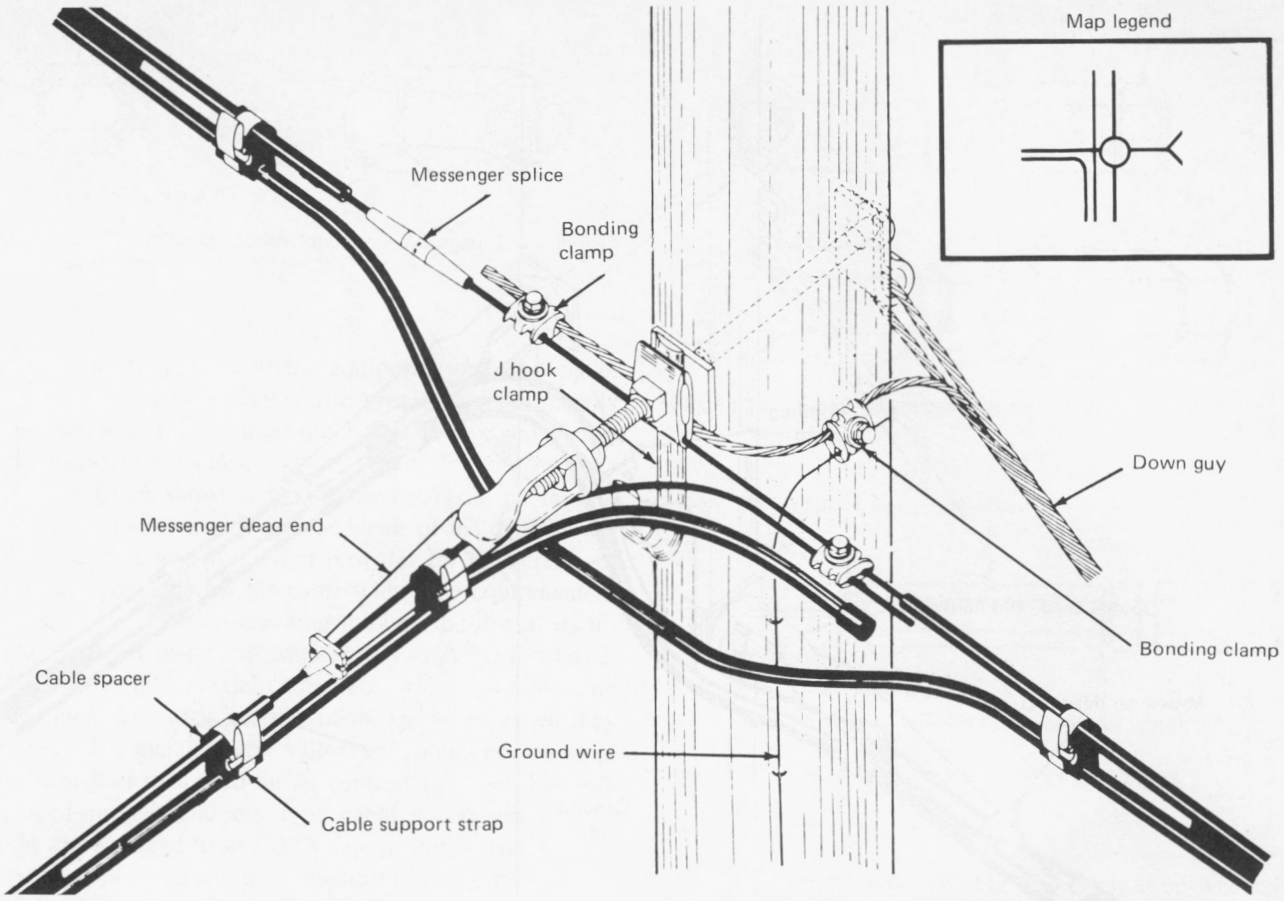


Fig. 13-13. Cable placing—line-pole dead-end combination 2 (*M/A Com Comm-Scope*).

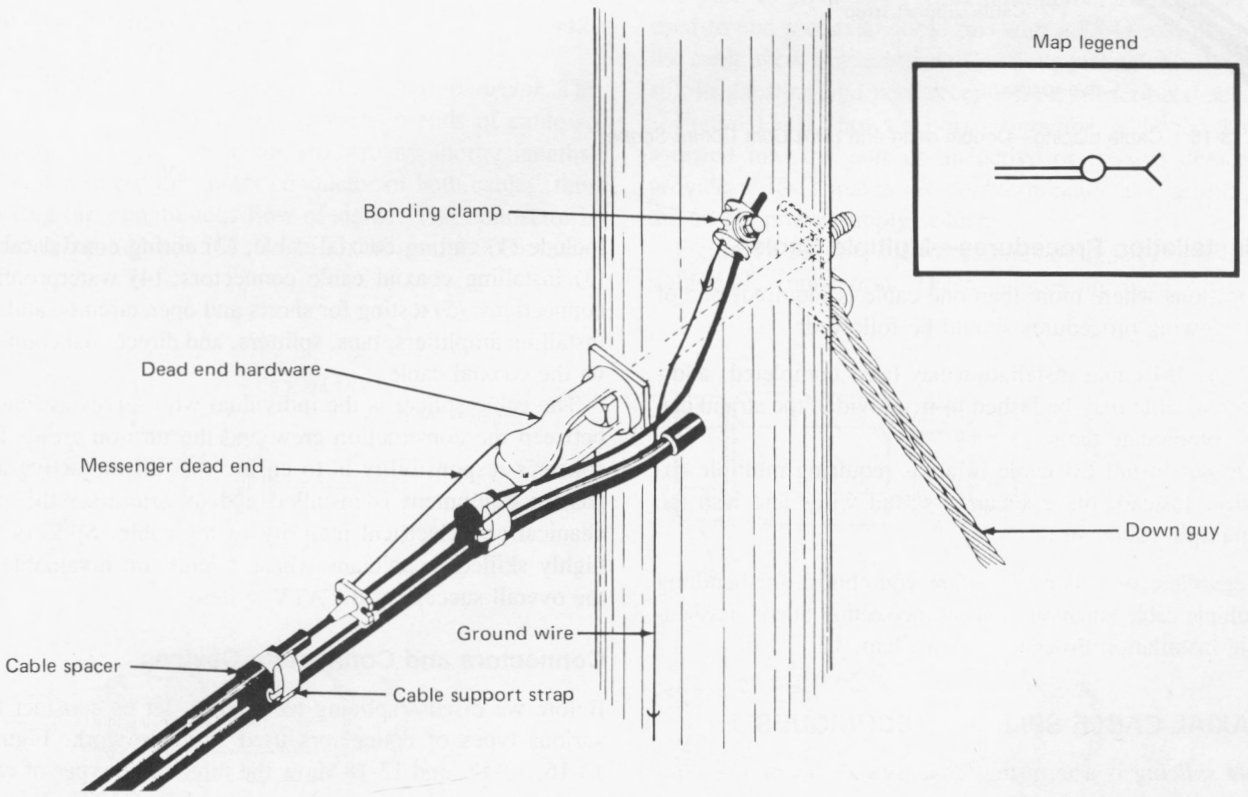


Fig. 13-14. Cable placing—dead-end (*M/A Com Comm-Scope*).

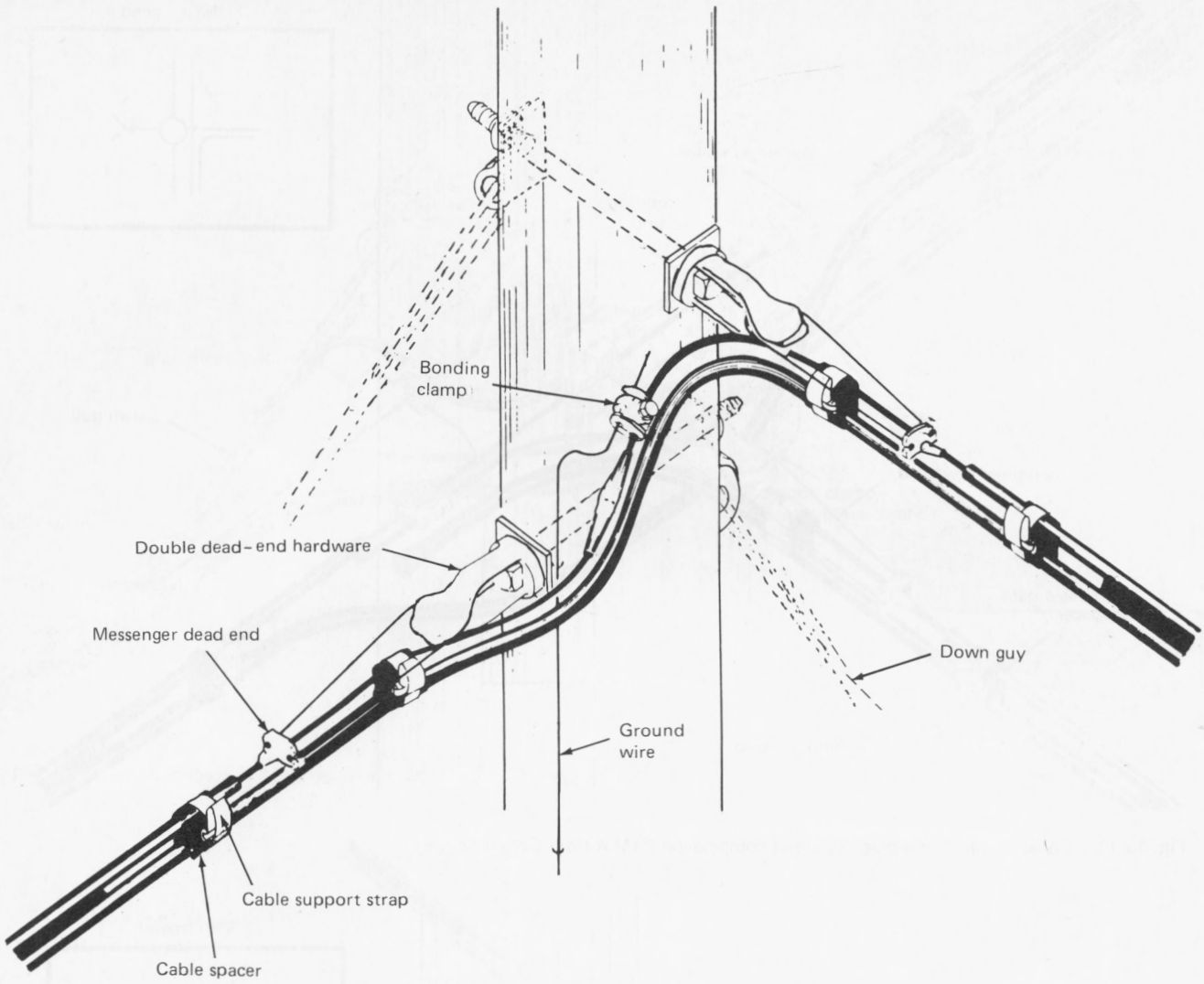


Fig. 13-15. Cable placing—Double dead-end (*M/A Com Comm-Scope*).

IM Installation Procedures—Multiple Cables

In locations where more than one cable is required, one of the following procedures should be followed:

1. If the IM cable installation has been completed, additional cable may be lashed to it, provided the strand can accommodate them.
2. Do not install IM cable in areas requiring multiple cables. Instead, place separate strand wires and lash the multiple cables to it.

Regardless of which procedure you choose for handling a multiple cable situation, consult the section titled "Lashed-Cable Installation Procedures" in Chap. 12.

COAXIAL CABLE SPLICING TECHNIQUES

Cable splicing is a term that describes all operations concerned with the preparation of previously installed coaxial cable. Some of the operations performed by cable "splicers" include (1) cutting coaxial cable; (2) coring coaxial cable; (3) installing coaxial cable connectors; (4) waterproofing connections; (5) testing for shorts and open circuits; and (6) installing amplifiers, taps, splitters, and directional couplers on the coaxial cable.

The cable splicer is the individual who serves as liaison between the construction crew and the turn-on crew. The splicer's responsibility is to ensure that all the active and passive equipment is installed and to determine the mechanical and electrical integrity of the cable. Splicers are highly skilled technicians whose talents are invaluable to the overall success of a CATV system.

Connectors and Connecting Devices

Before we discuss splicing techniques, let us consider the various types of connectors used in cable work. Figures 13-16, 13-17, and 13-18 show the three basic types of captive center conductor connectors used in CATV. Figures 13-19 to 13-24 illustrate some of the specialized devices

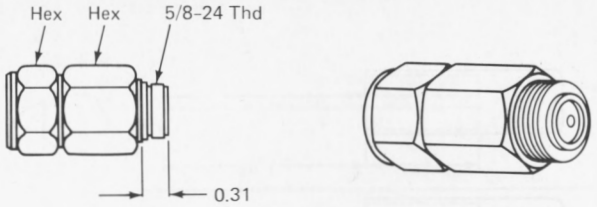


Fig. 13-16. Feed-through connector (Hex = hexagon: Thd = thread) (*Anixter Bros., Inc.*).

used by the splicers to fit the equipment onto the cable. The purpose of a connector is to provide a mechanically sound and waterproof connection between the coaxial cable and equipment housings.

Figure 13-16 shows a feed-through coaxial cable connector that allows the center conductor of the cable to extend from its body. Its design provides for the seizing of the center conductor of the cable within the equipment. It also provides superior shielding through the use of its integral sleeve. This type of connector is available for 0.412, 0.500, and 0.625 coaxial cable. The sizes of the hexagon (Hex) nuts vary with the size of the cable on which they are used. The manufacturer's literature should be consulted for the size of nuts used on all connectors. Note that both the feed-through and pin type cable connectors have a $\frac{5}{8}$-24 screw thread to fit CATV equipment housings.

A *pin-type* coaxial cable connector is shown in Fig. 13-17. This connector provides a pin for seizing by the equipment. The center connector of the cable is seized by the connector itself, thus providing a direct connection with the pin. This type of connector is available for sizes 0.412, 0.500, 0.625, 0.750, and 1.000 coaxial cable.

Figure 13-18 shows a coaxial cable *splice connector*. The splice connector is used to join the two ends of cable so that a long run may be made from many shorter lengths. The splice seizes the center conductor of both cables, thus allowing for a continuous flow of signal. This connector is available for 0.412, 0.500, 0.625, 0.750, and 1.000 coaxial cable.

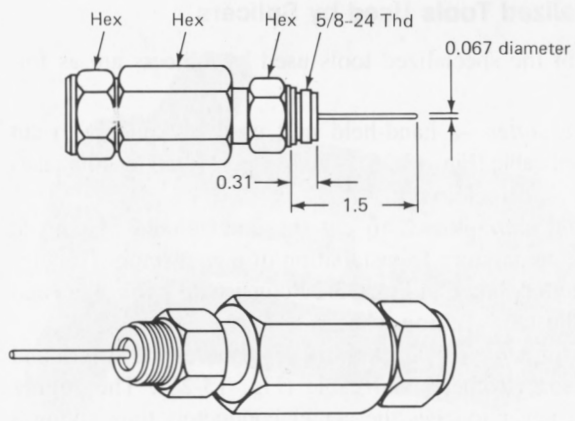


Fig. 13-17. Pin-type connector (*Anixter Bros., Inc.*).

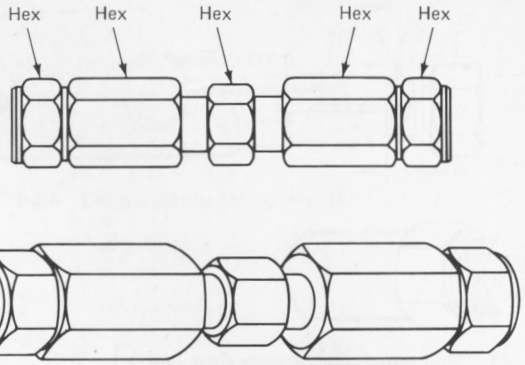


Fig. 13-18. Splice connector (*Anixter Bros., Inc.*).

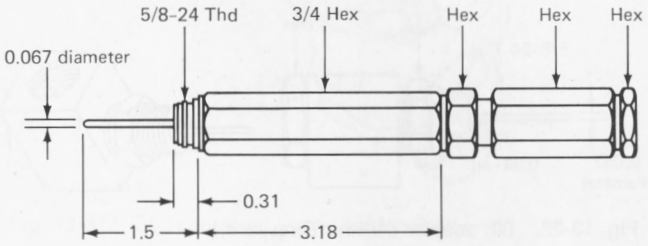


Fig. 13-19. Extension connector (*Anixter Bros., Inc.*).

An *extension connector* (Fig. 13-19) is used whenever there is insufficient cable to "mate" with the housings of either active or passive devices.

Figure 13-20 shows a *cable terminator*. Terminators are used to end a coaxial cable run with a 75-Ω resistance. If the cable were not terminated, serious mismatch would result in ghosting and poor reception on subscribers' sets.

Figure 13-21 shows a *port terminator*, a device that is screwed into the port of an active or passive device to provide a 75-Ω match. A port terminator also terminates the 60-Hz power supply voltage.

Figure 13-22 shows a *90° adapter* designed to provide a right-angle connection. These devices are used wherever

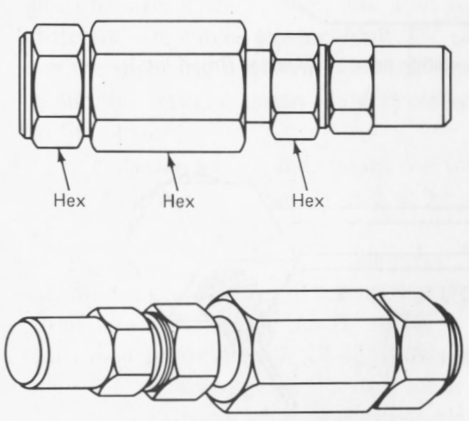


Fig. 13-20. Cable terminator (*Anixter Bros., Inc.*).

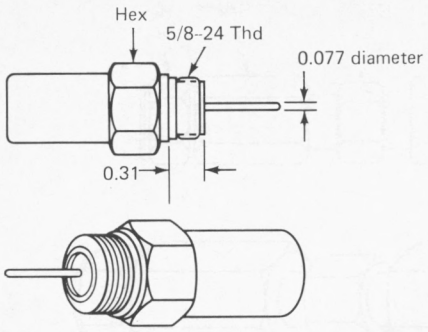


Fig. 13-21. Port terminator (*Anixter Bros., Inc.*).

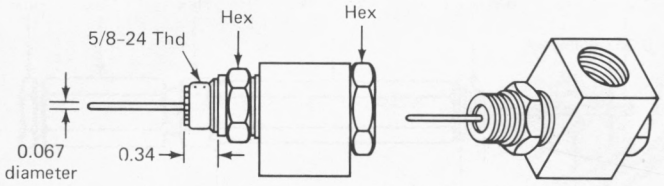


Fig. 13-22. 90° adapter (*Anixter Bros., Inc.*).

space is at a premium such as in a pedestal. A pedestal is a housing used in underground cable construction.

The *splice block adapter* shown in Fig. 13-23 contains two female ports used to couple two cables equipped with male fittings.

Figure 13-24 shows a *180° adapter* that provides a connection between an equipment housing and a connector when both are located in a restricted space.

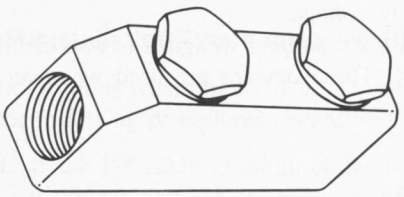


Fig. 13-23. Splice-block adapter (*Anixter Bros., Inc.*).

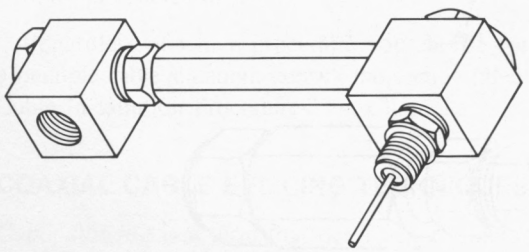


Fig. 13-24. A 180° adapter (*Anixter Bros., Inc.*).

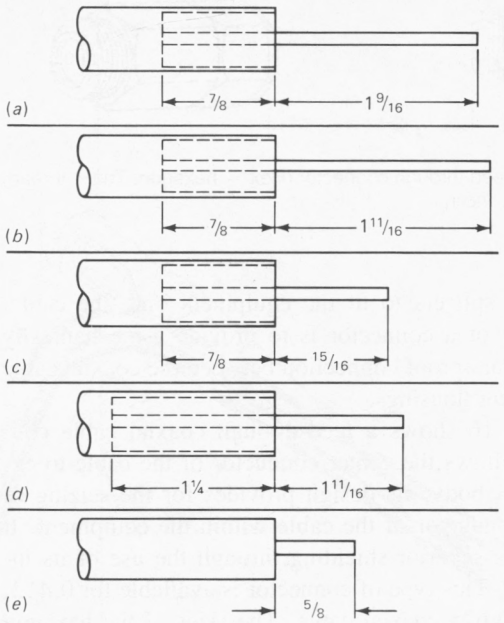


Fig. 13-25. Cable trim and coring dimensions (*Anixter Bros., Inc.*).

Cable Trim and Coring Dimensions

Figure 13-25 shows the cable trim and coring dimensions for various types of connectors and connecting devices. Figure 13-25*a* shows the dimensions for feed-through connectors with integral sleeves used on 0.412 and 0.500 coaxial cable. Figure 13-25*b* shows the dimensions for a feed-through connector with an integral sleeve used for 0.750 cable. The dimensions given in Fig. 13-25*c* are for pin-type connectors, splices, extensions, and terminators with integral sleeves used on 0.412, 0.500, 0.625, 0.750, and 0.825 coaxial cable. Figure 13-25*d* shows the dimensions for pin-type connectors and splices used on 1-in. cable having an integral sleeve. Figure 13-25*e* gives the dimensions for pin-type connectors, splices, and extensions, *without* an integral sleeve, used on 0.412, 0.500, and 0.750 cable.

Specialized Tools Used by Splicers

Some of the specialized tools used by splicers are as follows:

- *Cable cutter*—a hand-held unit used by splicers to cut coaxial cable (Fig. 13-26). The 8½-in. overall length makes it ideal for pole work.
- *Tubing cutter*—used to cut the outer shield of coaxial cable preparatory to installation of a connector. The tubing cutter shown in Fig. 13-27 consists of two rollers and an adjustable cutting wheel.
- *Coaxial cable preparation tool*—removes the sheath and dielectric from coaxial cable (Fig. 13-28). The cutting blade never touches the center conductor, thus giving a smooth, clean cut that does not distort or crush the cable.

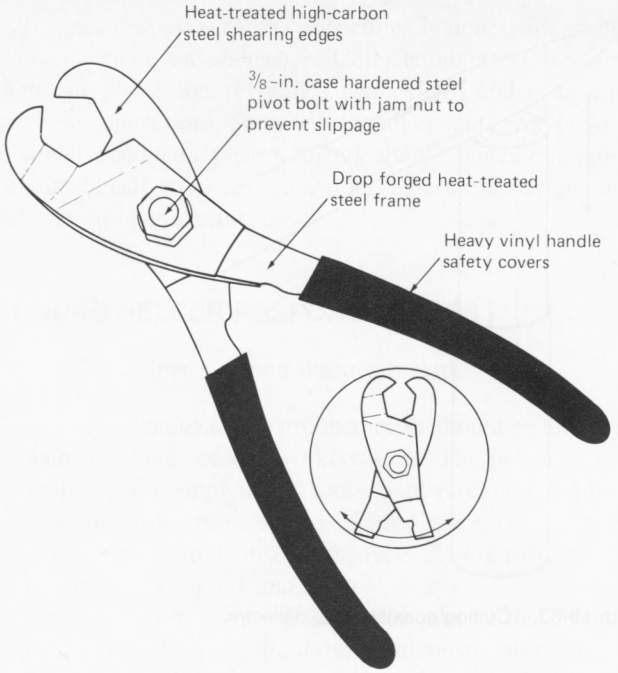

Heat-treated high-carbon steel shearing edges
3/8-in. case hardened steel pivot bolt with jam nut to prevent slippage
Drop forged heat-treated steel frame
Heavy vinyl handle safety covers

Fig. 13-26. Cable cutter (*Toner Cable Equipment, Inc.*).

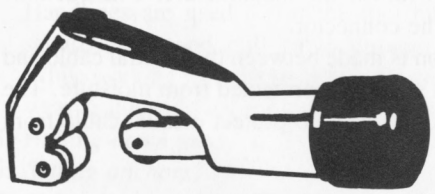


Fig. 13-27. Tubing cutter (*M/A Com Comm-Scope*).

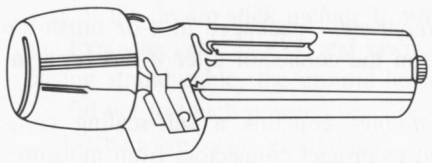


Fig. 13-28. Cable preparation tool (*M/A Com Comm-Scope*).

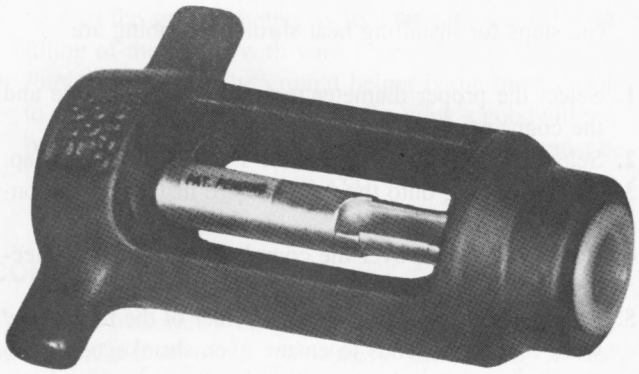


Fig. 13-29. Coring tool (*Lemco Tool Corp.*).

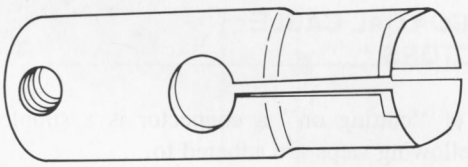


Fig. 13-30. Center conductor cleaner (*M/A Com Comm-Scope*).

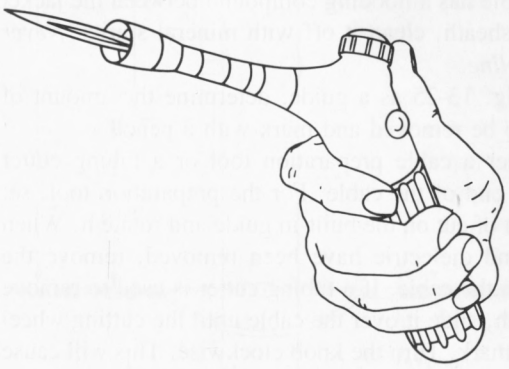


Fig. 13-31. Self-contained torch (*Anixter Bros., Inc.*).

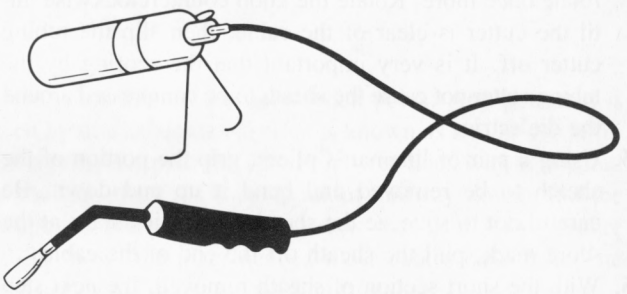


Fig. 13-32. Bottled propane torch (*Anixter Bros., Inc.*).

- *Coring tool*—used to remove the dielectric from between the sheath and the center conductor. A coring tool fits just one size of cable; therefore, a set is required for the different-size cables encountered. The purpose of coring out the dielectric is to provide space for insertion of the connector's integral sleeve. Typical coring tools are shown in Fig. 13-29.
- *Center conductor cleaner*—used to remove the small amount of dielectric that adheres to the center conductor (Fig. 13-30).
- *Propane torch*—basically of three types. The torch is used to shrink a special type of tubing that protects connectors from moisture. Figure 13-31 shows a hand-held, self-contained torch. Figure 13-32 shows a larger cylinder with 4 ft of hose connected to a torch head. The third type of torch has a 25-ft hose connecting the torch head to a 20- to 30-lb propane bottle that remains on the ground.

PREPARING COAXIAL CABLE FOR CONNECTORS

The technique of "cutting on" a connector is a simple process if the following steps are adhered to.

1. On jacketed cable, remove 4 in. of jacket material with either a tubing cutter or a knife. Be careful not to nick the sheath.
2. If the cable has a flooding compound between the jacket and the sheath, clean it off with mineral spirits. *Never use gasoline.*
3. Using Fig. 13-25 as a guide, determine the amount of sheath to be removed and mark with a pencil.
4. Slip either a cable preparation tool or a tubing cutter over the end of the cable. For the preparation tool, set the depth of cut on the built-in guide and rotate it. When sheath and dielectric have been removed, remove the tool from the cable. If a tubing cutter is used to remove the sheath, slide it over the cable until the cutting wheel is at the mark. Turn the knob clockwise. This will cause the cutting wheel to move toward the sheath. Advance the cutting wheel until contact is made. At this point turn the knob a half turn more and rotate around the cable once. Advance the cutter another half-turn and rotate once more. Rotate the knob counterclockwise until the cutter is clear of the cable, then slip the tubing cutter off. It is very important that the scoring by the tubing cutter not cause the sheath to be compressed around the dielectric.
5. Using a pair of lineman's pliers, grip the portion of the sheath to be removed and bend it up and down. Be careful not to squeeze the sheath. When it breaks at the score mark, pull the sheath off the end of the cable.
6. With the short section of sheath removed, the next step is to remove the dielectric. This is done by placing the edge of the electrician's knife on the dielectric at the point where the sheath was cut. While applying pressure, rotate the knife around the dielectric until the dielectric is cut almost to the depth of the center conductor. The next step is to cut away sections of dielectric by cutting along the center conductor toward the sheath. This procedure is shown in Fig. 13-33.
7. Remove any excess dielectric with either the center conductor cleaner or coarse steel wool. If steel wool is used, be careful not to scratch the copper coating.
8. Place the coring tool on the cable by inserting the center conductor into the hole provided for it in the cutter. Push the cutter into the dielectric and rotate clockwise until the proper depth is achieved. To remove the tool, continue to turn it clockwise and pull it off the end of the cable.
9. At this point, the end nut of the connector should be slipped over the coaxial cable. Next, insert the center conductor into the main section of the connector. After the center conductor is inserted, push the connector up to where the sheath was cut and tighten the end nut.

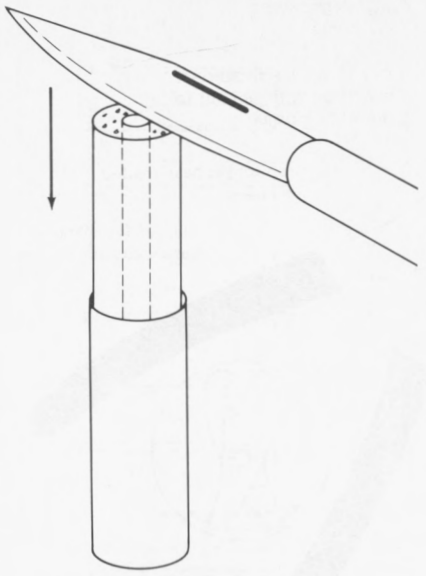


Fig. 13-33. Cutting coaxial cable dielectric.

These procedures are, of course, general in nature because there are many different styles of connectors. The best procedure would be to follow the manufacturer's instructions for installation of the connector.

After a connection is made between the coaxial cable and a housing, the joint should be protected from moisture. The more common products used to protect coaxial cable from moisture are:

- *Silicone grease*—placed on the threads of each nut before they are tightened onto the connector body. Silicone grease is packaged in 8-oz tubes and is squeezed out onto the threads.
- *Liquid rubber (Neoprene)*—packaged in 4-oz brush-top cans and painted on the connector after it has been installed.
- *Heat-shrinkable tubing*—contains a self-sealing compound and is used to protect connectors from moisture, fungus, and corrosion. Heat-shrinkable tubing can be purchased either in bulk or in precut lengths and is available in diameters ranging from ¾ to 2 in.

The steps for installing heat shrinkable tubing are:

1. Select the proper diameter to cover both the cable and the connector.
2. Select a length that will provide 1½ to 2 in. of overlap.
3. Slip the tubing onto the cable before installing the connector.
4. Center the tubing over the completely installed connector.
5. Using a torch, apply heat to the center of the tubing and work toward the ends to ensure even shrinkage.
6. Continue to apply heat until the sealing compound can be seen coming out from around each end of the tubing.

Testing of coaxial cable connections is done with an instrument called an *ohmmeter*. Connections are tested for short circuits (a low-resistance connection) and open circuits (no connection). Sheath-to-sheath or center conductor-to-center conductor measurements should indicate a short circuit. Sheath-to-center conductor measurements should indicate an open circuit.

GROUND HELPER RESPONSIBILITIES

The ground helper's responsibilities include:

1. *Assisting climbers*. The ground helper should be familiar with the duties of the workers aloft. The helper is responsible for supplying all tools, hardware, and supplies to a climber. Before work is started, the ground helper and climbers should discuss the type of work to be done.
2. *Placing safety cones and signs*.
3. *Flagging traffic*. One of the major jobs of the ground helper is to direct traffic during the construction phase. The person chosen should take the responsibility for safeguarding his or her fellow workers seriously.
4. *Using handlines*. The handline, in the hands of an experienced ground helper, becomes a versatile tool. Handlines are used to lift the tool bucket to climbers, secure lines, and pull cable through trees and brush. While working with the handline, the ground helper should wear leather gloves for hand protection.
5. *Pulling down guys*.
6. *Setting anchors*.
7. *Using lay-up sticks*. The lay-up stick is used, with the proper head, to place cable into J hooks or cable blocks. This job falls to the ground helper and must be done correctly to ensure the steady flow of construction. Other uses of the lay-up stick include trimming trees, placing and removing cable blocks, and sawing tree limbs. When raising strand cable, the ground helper should be very careful not to touch power lines. Rubber gloves should always be worn by the ground helper whenever stringing strand on poles containing power lines.
8. *Pulling and maintaining cable lashing machines*. Periodically the ground helper will be called on to pull the lashing machine. Another job related to the lasher that falls to the ground helper is its lubrication and the refilling of the lasher with wire.
9. *Public relations*. The ground helper is the most visible to the public and thus becomes the crew's goodwill ambassador. With this in mind, the ground helper must be knowledgeable about all aspects of CATV work.

CONSTRUCTION CODES

To ensure uniformity in the construction of CATV, telephone, and electric power, guidelines in the form of "codes" are used. Because most of the present cable systems utilize aerial construction, we will emphasize the placement of these wires and cables on wooden poles. Any pole that is used by more than one service is known as a *joint-use pole*. On a joint-use pole the electric power lines will be located at the top, the CATV cable about midway down, and the telephone company service below that of CATV. Figure 13-34 shows the placement of these cables on a pole. The measurements given are minimum values.

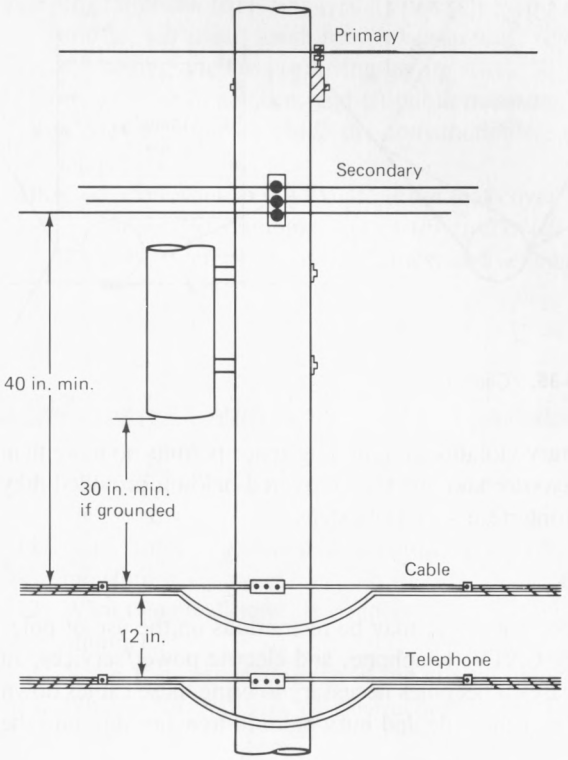


Fig. 13-34. Spacings on a joint-use pole.

Because of the wide variations in codes, the values given here will be general rule of thumb and are not to be taken literally. It is suggested that either the city or the county engineer be consulted for exact values.

Wooden Pole Location Guidelines

Wooden poles that are used to support either electric power, telephone, or CATV should not interfere with vehicle or pedestrian traffic. As a general rule, poles are placed 3 ft from fire hydrants, signal pedestals, or street lights. They also should be 6 in. from the curbline and no closer than 12 ft to railway tracks.

Climbing Space

When a worker must ascend a pole, sufficient space should be available that is free of obstructions. The amount of climbing space that should be allotted to a worker is 30 in. sq. for a distance of 48 in. above and 48 in. below the cable. Various examples are shown in Fig. 13-35.

Sometimes it becomes necessary to compromise the climbing space temporarily. The guidelines that cover the

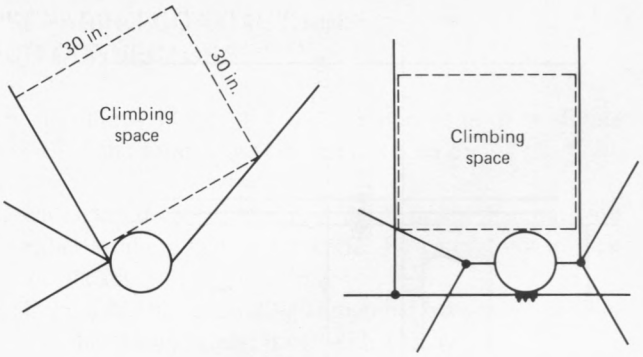


Fig. 13-35. Climbing space.

temporary violation of climbing space permits no more than one guy wire and one riser (covered below), provided they do not interfere with pole steps.

Risers

In some areas there may be restrictions on the use of poles to carry CATV, telephone, and electric power services. In these cases it becomes necessary to bring these cables down the side of the pole and bury them in trenches dug into the ground.

These vertical runs are known as "risers." A riser may also be a ground wire that runs from the power company's neutral to a ground rod driven into the earth. The codes that cover risers specify that they be covered by either steel pipe, nonmetallic tubing, or wooden molding. The codes also specify that these guards be 8 ft above the ground, in the case of power, telephone, or CATV, and 7 ft from the ground in case of a ground wire.

The methods of covering risers or ground wires are shown in Fig. 13-36.

Coaxial Cable between Poles and Buildings

A coaxial cable running between a pole and a building must be located at a distance of at least 12 in. from electric power lines. The coaxial cable must also be self-supporting and at least 8 ft above the roof of any building that has pedestrian traffic.

Coaxial Cable Attached to Buildings

Coaxial cable attached to a building must not be less than 4 in. from electrical power conductors or within 6 ft of lightning conductors. The coaxial cable may be placed any distance from the surface of the building but must not interfere with other communications systems.

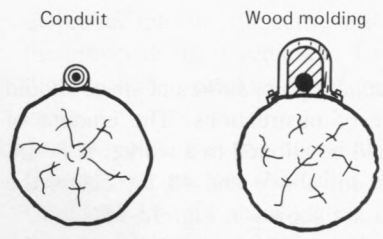


Fig. 13-36. Methods of covering risers and ground wires.

Coaxial Cable within a Building

Coaxial cable within a building must not be closer than 2 in. to electrical power or lighting conductors unless the power or lighting conductors are located in conduit or raceways, nonmetallic sheathed cable, or type UF cable or are separated from the coaxial cable by a nonmetallic separator. These requirements also apply to shafts within the building. Coaxial cable may not be installed in boxes containing electric power conductors unless separated by a permanent partition. Coaxial cable may be in the same box, without separation, if the conductors are used to power CATV distribution equipment. Coaxial cables that are bunched together must be covered with a fire-resistant covering or be enclosed in a noncombustible tubing. Any coaxial cable entering the building from underground through ducts, pedestals, hand holes, or manholes (covered in Chap. 14) must be separated from electric power or lightning conductors by a suitable barrier.

Grounding of Coaxial Cable

The grounding conductor (outer shield) of coaxial cable exposed to lightning or electric power of over 300 V must be connected to ground. The more common method of accomplishing this is to connect the outer shield to (1) the nearest building ground system; (2) the power service conduit, enclosure, or grounding electrode system; (3) underground gas piping; or (4) a ground rod driven into damp earth.

Grounding to the above should be accomplished by a pipe-fitting, bolted clamp or a sheet-metal (strap-type) ground clamp. The physical grounding should be as close to the point of entry as possible, with the use of No. 18 AWG or larger wire. The ground wire should be run as straight as possible and be protected from physical damage.

In addition to the above codes, it is recommended that article 820 of the National Electrical Code® (NEC®) be understood by all CATV workers.[1]

SUMMARY

1. Integrated messengered cable is coaxial cable with strand incorporated within the jacket.
2. A splicer is an individual who installs connectors and equipment on coaxial cable.
3. The three basic types of connectors are the feed-through, the pin types, and the splice.
4. A captive center conductor connector is one that seizes the center conductor of the coaxial cable, thereby ensuring good electrical contact.

[1]National Electrical Code® and NEC® are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA.

5. The standard-size fitting on equipment housings is 5/8 in.-24.
6. Some of the specialized tools used by splicers include the (*a*) cable cutter, (*b*) tubing cutter, (*c*) coaxial cable preparation tool, (*d*) coring tool, (*e*) center conductor cleaner, and (*f*) propane torch.
7. Some of the products that protect connectors from moisture, corrosion, and fungus are (*a*) silicone grease, (*b*) liquid rubber (Neoprene), and (*c*) heat-shrinkable tubing.
8. The ground helper's responsibilities include (*a*) assisting climbers, (*b*) placing safety equipment, (*c*) flagging traffic, (*d*) using handlines, (*e*) installing down guys, (*f*) setting anchors, (*g*) using lay-up sticks, (*h*) lashing machine maintenance, and (*i*) public relations.
9. Codes are used to guide the construction of a CATV plant.
10. Codes relevant to CATV are those that cover (*a*) pole locations, (*b*) climbing space, (*c*) risers, (*d*) coaxial cable between poles and buildings, and (*e*) coaxial cable within a building.

REVIEW QUESTIONS

1. Define IM coaxial cable.
2. Describe the drive-off route method of IM cable installation.
3. Describe the back-pull method of IM cable installation.
4. Describe the back-pull–winch method of IM cable installation.
5. Name five operations performed by cable splicers.
6. Name the three basic types of captive center conductor connectors.
7. What is the function of a port terminator?
8. Name five specialized tools used by splicers.
9. Describe the process of preparing a jacketed coaxial cable for the installation of a connector.
10. What should be used to clean flooding compound from the sheath?
11. Name three products used to protect connectors from moisture.
12. What two conditions are connections tested for with an ohmmeter?
13. Name five responsibilities of the ground helper.
14. What is the amount of obstruction-free space made available to the climber?
15. Name three acceptable methods of grounding the sheath of coaxial cable exposed to lightning or voltages over 300 V.

14 CHAPTER

UNDERGROUND CABLE CONSTRUCTION

INTRODUCTION

In this chapter you will learn about:

1. The various enclosures used in underground construction
2. The specialized tools used in underground construction
3. The techniques used to install underground cable plant

The construction of an underground CATV system is both time-consuming and expensive. Because of this, cable companies have always preferred to string their cables on poles. In the past few years more and more building codes are requiring underground construction for all utilities. In new subdivisions, it is not uncommon for power, telephone, and cable to share the same trench or duct system.

The underground construction process begins with a survey of the area to be served. After the survey is completed, the proposed route is mapped out. These maps contain not only the location of the other utilities and property lines, but also any other information needed by the construction crew.

Before construction is begun, the residents of the area to be served are notified and any questions answered. The utility companies will also be notified and asked to place markers along their route so that their lines can be avoided.

An underground cable installation can take many forms. The more common forms of installation include (1) direct burial using pedestals, (2) direct burial using conduit and pedestals, (3) direct burial using hand holes, (4) direct burial using vaults, and (5) cable being placed in ducts and accessed by manholes.

UNDERGROUND CONSTRUCTION ENCLOSURES

Cable TV enclosures are used to provide access to the equipment as well as protection for the cable. Enclosures also give limited protection from theft, rodents, and excessive moisture. Some enclosures are placed above the ground, while others are buried below ground level. The following enclosures are used to house CATV cables and equipment.

Pedestals

A pedestal is a box used to hold cable equipment above the ground. Figure 14-1 shows a typical pedestal used in cable systems. The main purpose of a pedestal is to provide a place where attachments, adjustments, and maintenance of the system can occur. Pedestals are mounted on metal stakes that are driven into the ground.

Pedestals are available in many sizes ranging from those used to house taps on up to those used for trunk stations. Figure 14-2 shows a variety of pedestals used in the cable industry. Within the pedestals are brackets used to mount the equipment securely. Figure 14-3 illustrates the various markings contained on the lid of a pedestal. Figures 14-4 and 14-5 demonstrate two uses of pedestals.

Conduit

In areas where extra protection is needed, coaxial cable is placed in conduit. Conduit is plastic or metal pipe that provides protection from moisture, sharp rocks, rodents, and physical stresses. Conduit used in CATV is available in 10-ft lengths and diameters ranging from 1 to 3 in. *Couplings* join lengths of conduit together, and *elbows* or *bends* allow turns to be made. Plastic [polyvinylchloride (PVC)] conduit is cemented together, while metal conduit is screwed together. The ends are sealed with duct sealant. Figure 14-6 shows a 5-lb bag of duct sealant.

Other Housings

Three other types of cable housing are:

1. *Hand holes*—covered housings that are placed at ground level to allow access to taps and splices. Figure 14-7 shows a hand hole used in CATV.
2. *Vaults*—a cinder block or concrete box set below ground level to house amplifiers, splitters, taps, directional couplers, and splices. Vaults are equipped with lids to permit access and drain holes to relieve water buildup. Figure 14-8 is a top view of a buried-plant housing (vault). Shown are the cables entering and leaving as well as the trench and bend radius requirements.
3. *Manholes*—a concrete or brick structure that is set below the surface of the ground. Manholes are accessed by removing a steel cover that is flush with the street. Manholes range in size, depending on their application, but average 6 ft wide and 10 ft long. Round manholes are about 6 ft in diameter. The average height of a manhole is 7 ft. The floor contains a drain to prevent water from

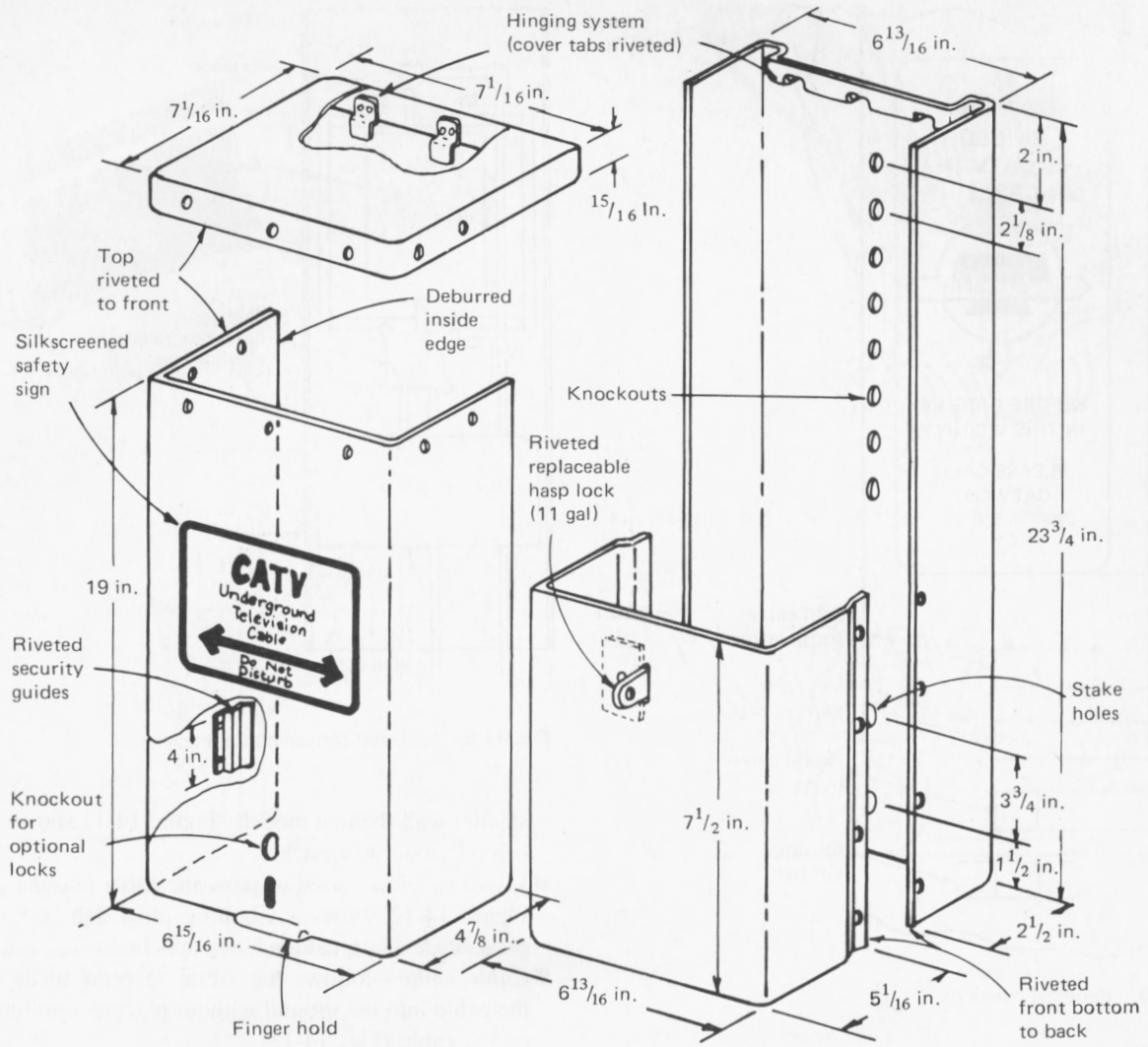


Fig. 14-1. Pedestal construction (*CWY Electronics*).

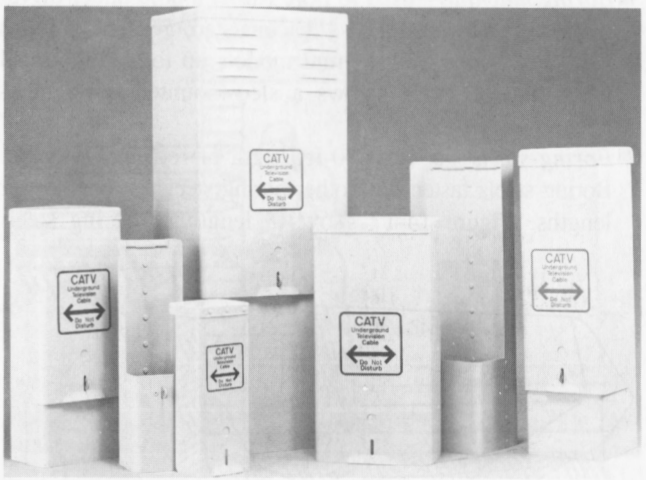


Fig. 14-2. Various sizes of pedestals (*CWY Electronics*).

building up. Coming into and leaving the manhole are concrete pipes called *ducts*. These ducts run from manhole to manhole and are used to provide a passageway for the cable. Figure 14-9 shows a worker feeding cable into a duct.

UNDERGROUND CONSTRUCTION TOOLS AND EQUIPMENT

Some of the specialized tools and equipment used to place coaxial cable underground are as follows:

- *Sod cutter*—used to cut sections of grass along the trench line (Fig. 14-10). The sod is cut to a depth of 1 in. and a width of 12 in.
- *Trencher*—used to dig a trench 12 to 18 in. deep for cable to lay in. Most trenchers used for CATV work are the

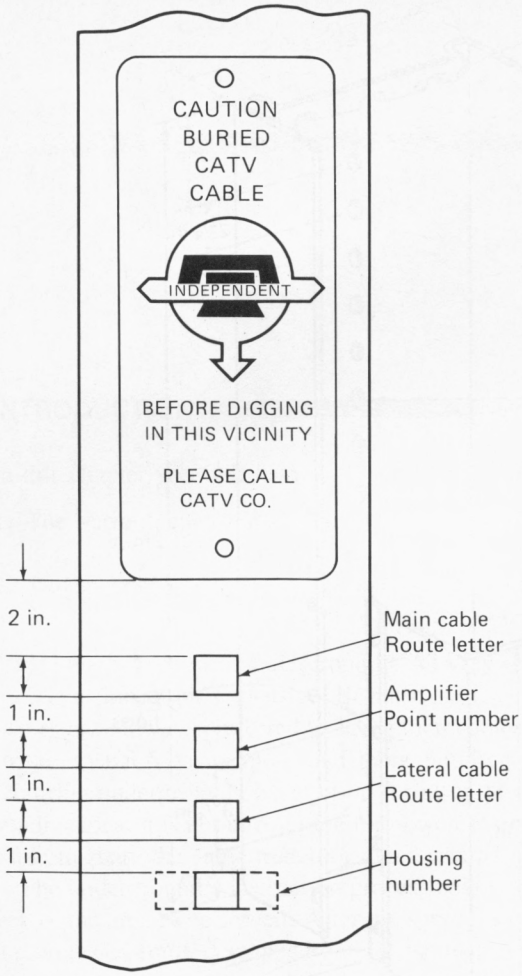


Fig. 14-3. Pedestal markings.

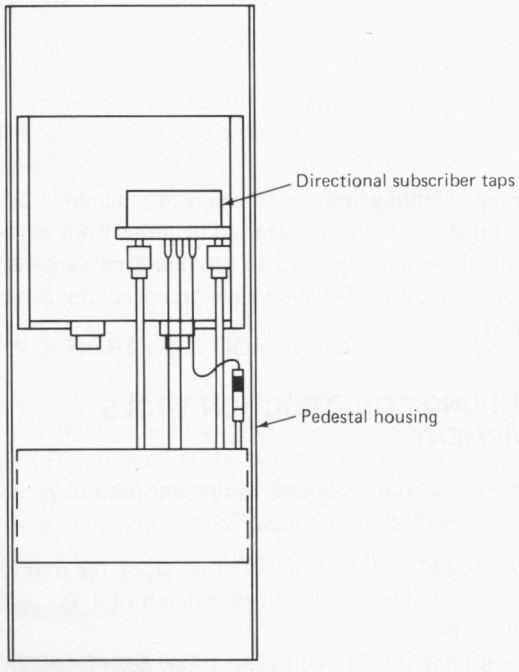


Fig. 14-4. Pedestal containing a tap.

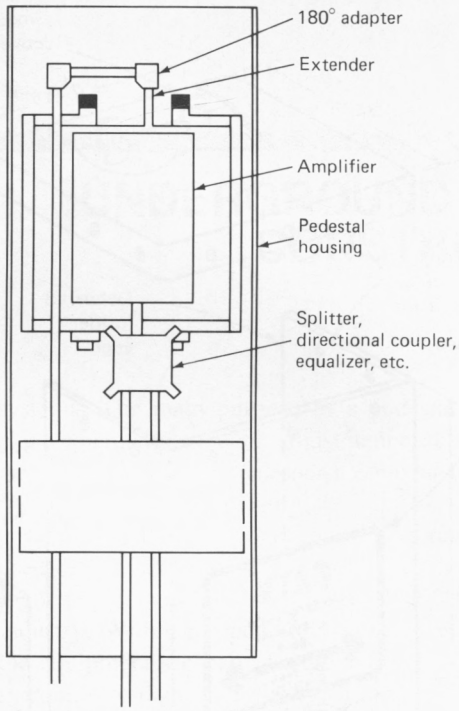


Fig. 14-5. Pedestal containing an amplifier.

smaller walk-behind models. Figure 14-11 shows a walk-behind model of trencher.

- *Vibrating plow*—used to plow the cable into the ground. Figure 14-12 shows a vibrating plow and two sizes of plow blades with cable chutes attached.
- *Cable chute*—follows the vibrating plow blade to feed the cable into the ground without placing a pulling strain on the cable (Fig. 14-13).
- *Backhoe*—used for digging bore pits (holes for boring machines to be covered later) and other general-purpose trenching jobs. Figure 14-14 illustrates a medium-sized backhoe.
- *Trailer*—used to transport underground machinery to and from the job site (Fig. 14-15).
- *Boring machine*—used to bore (drill) a hole under driveways and sidewalks. These machines are available in sizes that range from walk-behind models up to sled-mounted units. Figure 14-16 shows a sled-mounted boring machine.
- *Boring steels*—a 4- to 10-ft length of rod or steel pipe. Boring steels fasten onto other boring steels to form longer lengths. Figure 14-17 shows a length of boring steel.

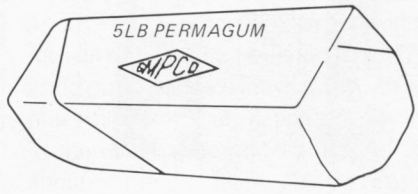
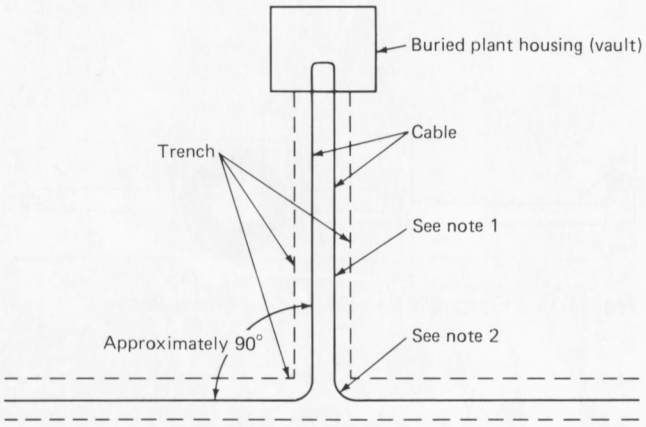


Fig. 14-6. Duct sealant (*Anixter Bros,. Inc.*).

Fig. 14-7. Hand hole (*Anixter Bros., Inc.*).



1. The in and out laterals to the buried plant housing shall be located in the same trench.
2. The radius of bend of the cable shall not be less than 20 times the diameter of the cable or wire.

Fig. 14-8. CATV vault (top view).

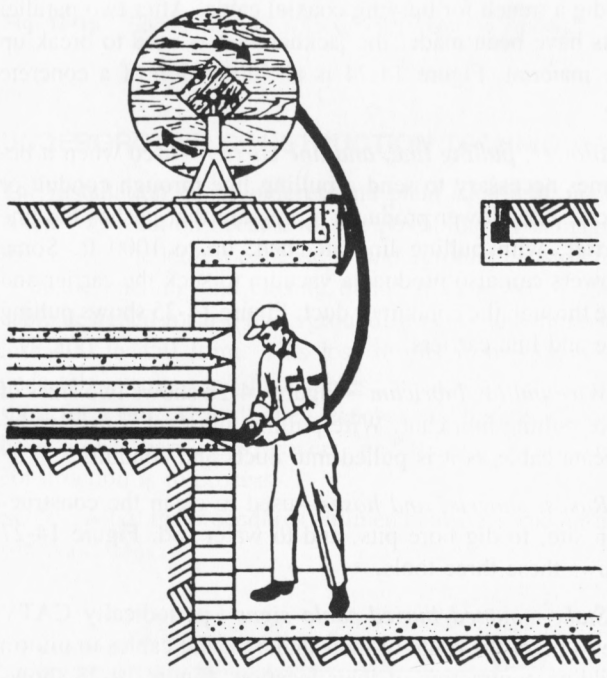


Fig. 14-9. Manhole and ducts.

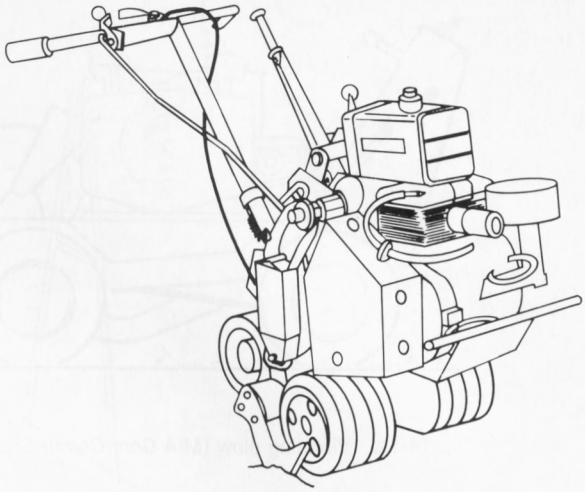


Fig. 14-10. Sod cutter (*M/A Com Comm-Scope*).

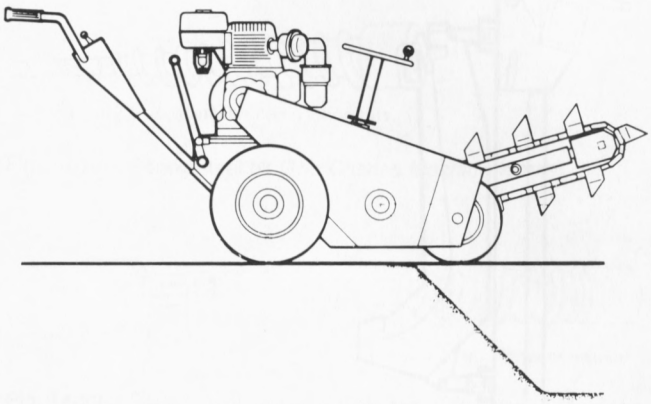


Fig. 14-11. Trenching machine (*M/A Com Comm-Scope*).

These units are inserted into a boring machine, fitted with a bit, and used to bore holes.

- *Boring steel levels and guides*—used to level and guide boring steel sections during the boring operation. Figure 14-18 shows a boring steel level and guide.
- *Boring steel bits*—attached to the boring steel and used to cut and compact holes (Fig. 14-19).
- *Swivels and reamers*—used on the end of a boring steel to enlarge the bored hole (Fig. 14-20). They are also used to pull conduit or cable through the bore.

Rod pusher—pushes steel rods under streets, driveways, sidewalks, and other obstacles. A hydraulic rod pusher and associated equipment are shown in Fig. 14-21.

Push rod, reamers, and bits—Figure 14-22 shows push rod sections and a reamer. A push rod is a length of steel rod from 2 to 6 ft long. Rods are screwed together to form a longer length. Push rod reamers and bits are attachments used to penetrate the earth and increase the size of the bore. They are also used to pull conduit or cable back through the bore.

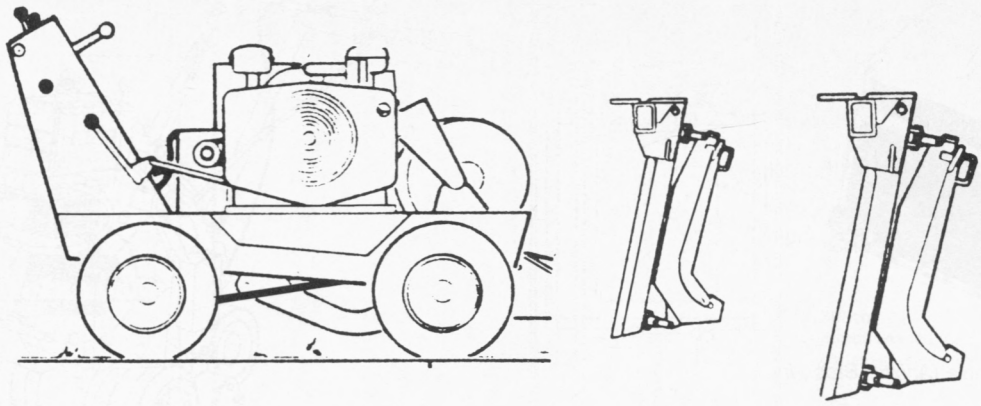


Fig. 14-12. Vibrating plow (*M/A Com Comm-Scope*).

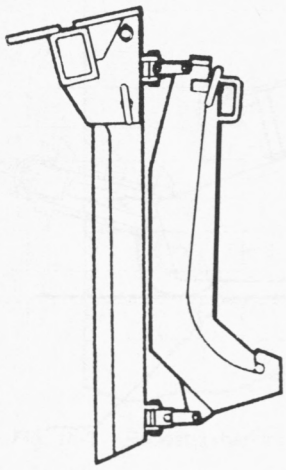


Fig. 14-13. Cable chute on vibrating plow blade (*M/A Com Comm-Scope*).

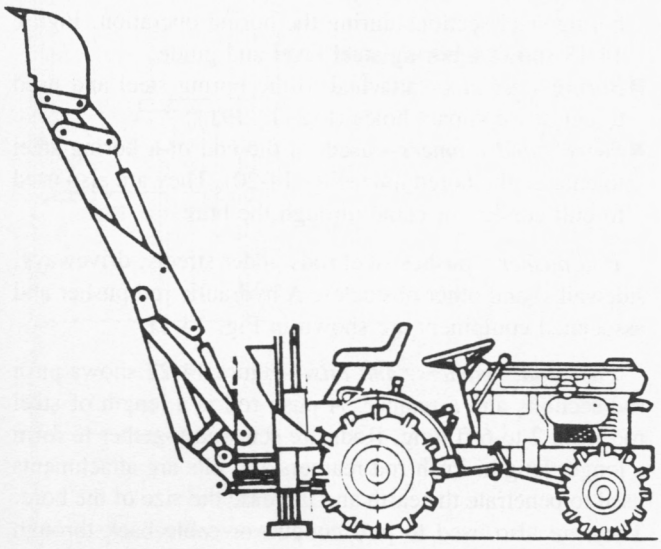


Fig. 14-14. Backhoe (*M/A Com Comm-Scope*).

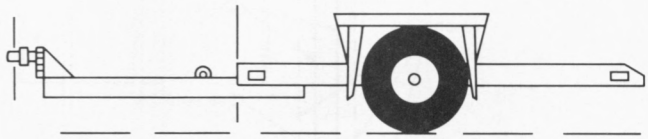


Fig. 14-15. Equipment trailer (*M/A Com Comm-Scope*).

Jackhammer and air compressor—used together to break up asphalt, concrete, and rock. Figure 14-23 shows a jackhammer and the compressor that supplies the air that operates it.

Concrete saw—used to cut sections out of streets in order to dig a trench for burying coaxial cable. After two parallel cuts have been made, the jackhammer is used to break up the material. Figure 14-24 is an illustration of a concrete saw.

Blower, pulling line, and line carrier—used when it becomes necessary to send a pulling line through conduit or ducts. The blower produces a pressure that pushes the line carrier, with pulling line attached, up to 1000 ft. Some blowers can also produce a vacuum to suck the carrier and line through the conduit or duct. Figure 14-25 shows pulling line and line carriers.

Wire-pulling lubricant—Figure 14-26 shows two sizes of wire-pulling lubricant. Wire-pulling lubricant is used to lubricate cable as it is pulled into ducts and conduits.

Rakes, shovels, and hoses—used to clean the construction site, to dig bore pits, and to water sod. Figure 14-27 shows these three tools.

Stake-mounted buried-cable signs—periodically CATV crews mark the route of their underground cables to inform building contractors of their location. Figure 14-28 shows three styles of stake-mounted signs.

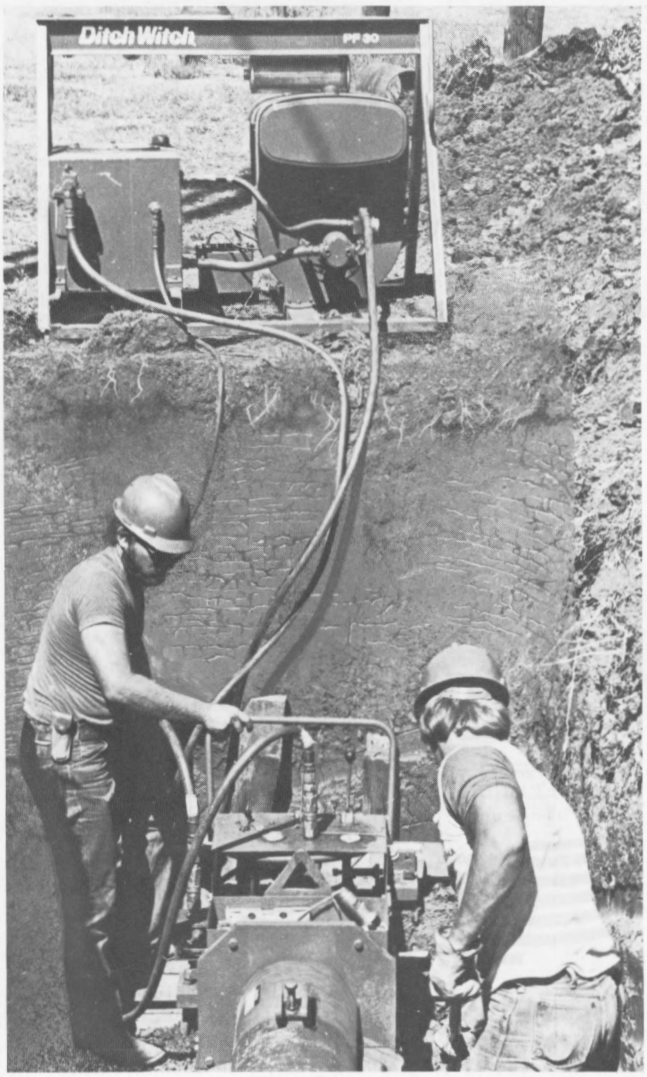


Fig. 14-16. Boring machine (*The Charles Machine Works*).

UNDERGROUND CONSTRUCTION TECHNIQUES

The installation of an underground plant should be undertaken with caution because of the possibility of damaging the cable. The largest expense in underground construction is in the opening and closing of the trench. When using cable designed for use underground, it is not uncommon to lose 400 to 450 ft/mi. This loss results from splicing in pedestals, vaults, and hand holes, as well as lengths too short for a run. Also all open trenches and bore pits should have proper barricades, covers, and flashing lights while construction is in process.

NOTE All of the procedures outlined below assume normal soil conditions.

Fig. 14-17. Boring steel section (*M/A Com Comm-Scope*).

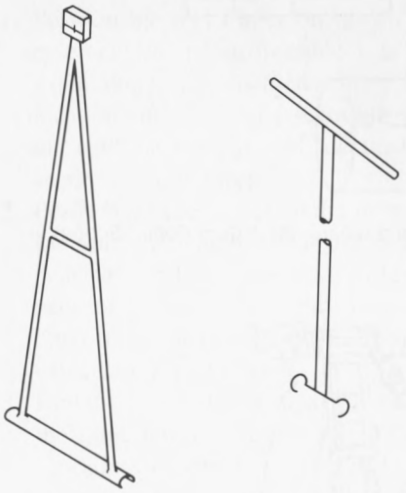


Fig. 14-18. Boring steel level and guide (*M/A Com Comm-Scope*).

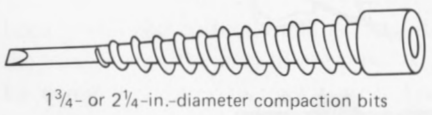


Fig. 14-19. Boring steel bit (*The Charles Machine Works*).

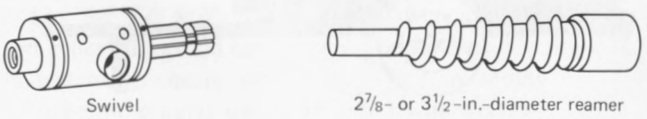


Fig. 14-20. Boring steel swivel and reamer (*The Charles Machine Works*).

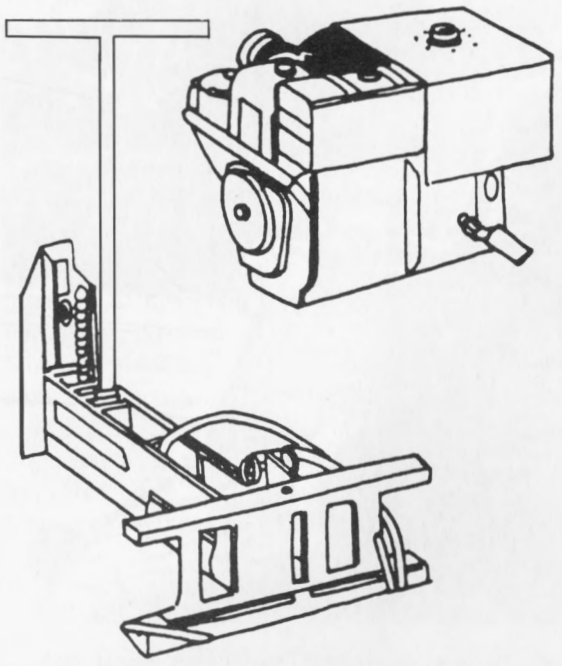


Fig. 14-21. Hydraulic rod pusher (*M/A Com Comm-Scope*).

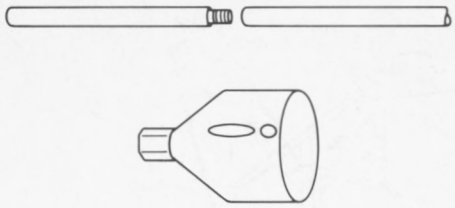


Fig. 14-22. Push rod and reamer (*M/A Com Comm-Scope*).

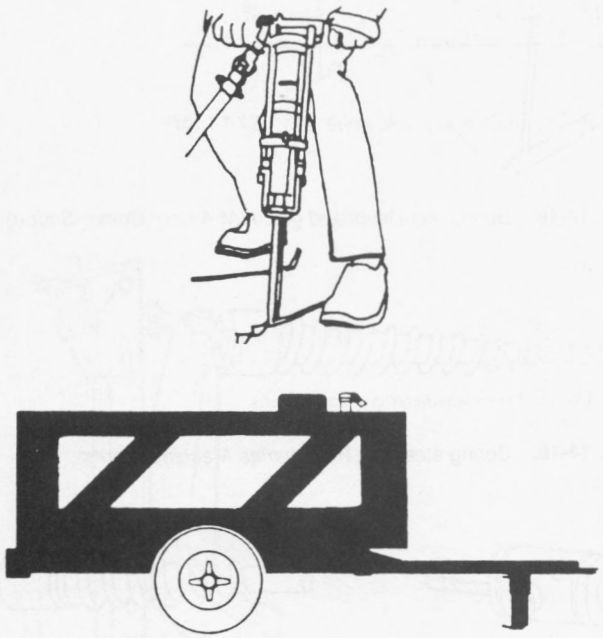
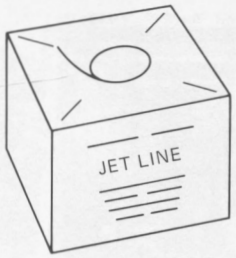


Fig. 14-23. Jackhammer and air compressor (*M/A Com Comm-Scope*).

Fig. 14-24. Concrete saw (*Federal Mogul Corp. Target Products Division*).



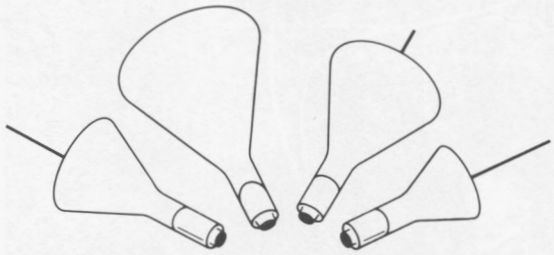


Fig. 14-25. Pulling line and line carriers (*M/A Com Comm-Scope*).

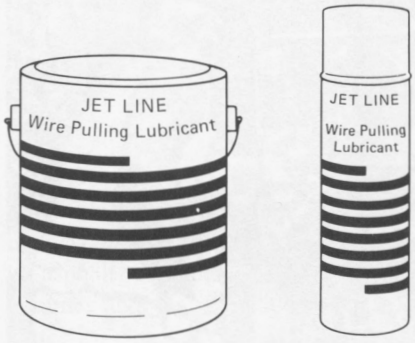


Fig. 14-26. Wire pulling lubricant (*M/A Com Comm-Scope*).

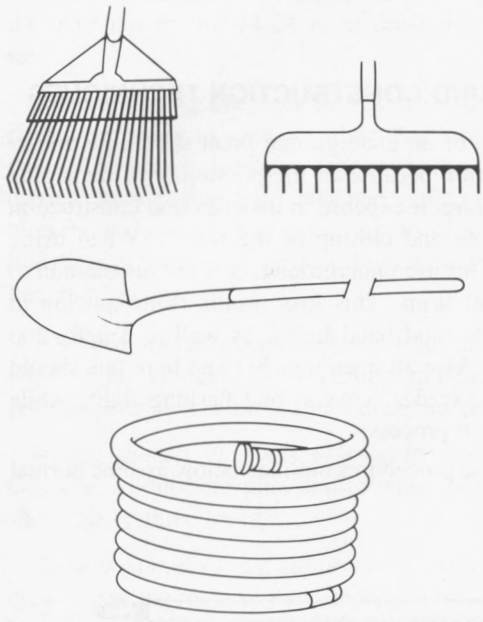


Fig. 14-27. Rakes, shovel, and hose (*M/A Com Comm-Scope*).

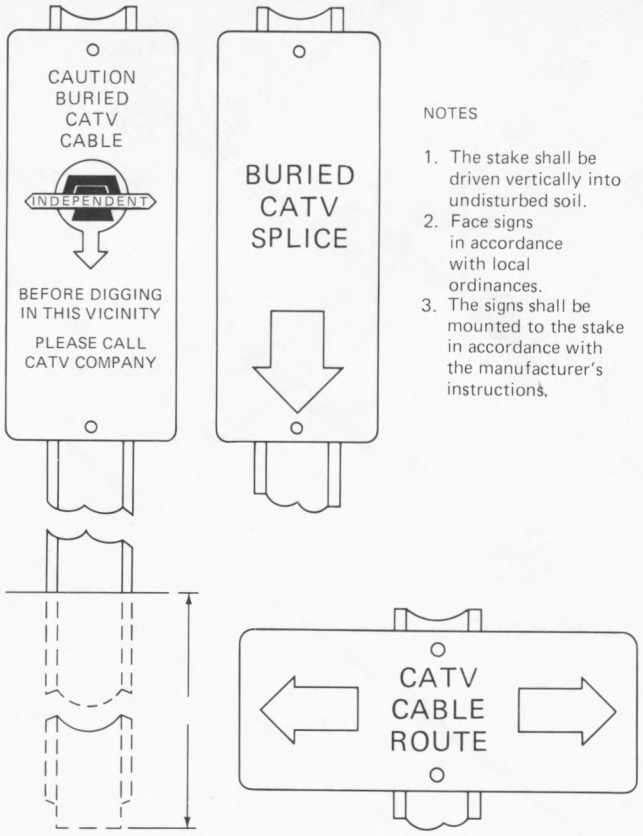


Fig. 14-28. Buried-cable warning signs.

Before beginning construction, the property owners, as well as the utilities, should be notified. Plowing and trenching should be in accordance with local codes and completed in no more than 2 days.

After all the tools, cable, and hardware needed are assembled, the crew proceeds to the construction site.

Installation Procedures—Easement Routes

At the construction site, safety equipment is placed along the route that extends beyond private property and the reel covers are removed.

Trenching—Single Cable Routes

The first job in the trenching operation is to remove the sod. Sod is removed with a sod cutter in 5-ft lengths and placed alongside the proposed trench. The trencher is then used to dig a trench 12 to 18 in. deep and as narrow as possible. If a fence is encountered, hand tools are used to dig under the fence to continue the trench. When the trench is completed, pedestals are staked at the proper locations. Figure 14-29 shows the trenching and sod cutting operations.

There are three ways to place the cable between the pedestals (see also Fig. 14-30):

1. Position the reel trailer on the street at the end of the easement as shown in cable 1 in Fig. 14-30. Pull the cable along the trench, leaving a loop at each pedestal location until the entire section is covered. Cut and cap the cable at the pedestal locations and push the cable sections into the trench.
2. Position the reel trailer on the street in front of the house. Measure the length of cable needed to extend between pedestals and cut enough to allow for fitting into the pedestal. After capping the ends, carry the cable to the open trench and drop it in. This method is shown as cable 2 in Fig. 14-30.
3. Roll the reel trailer to the first pedestal, then start feeding the cable into the trench toward the next pedestal. This procedure is seen as cable 3 in Fig. 14-30.

Prior to cutting the cable, be sure that there is sufficient cable protruding from the trench to reach the pedestal. A cable jig (Fig. 14-31) should be used to position the cable so that it enters the pedestal correctly. After the cable has been positioned correctly and is lying flat on the bottom of the trench, start the backfilling process. Backfilling is done by using the materials that were taken from the trench, removing all sharp rocks whenever necessary. To protect the cable in rocky soil, apply a 4-in. layer of sand to the bottom of the trench. When filled, tamp the soil, leaving enough soil to settle.

Lay the 5-ft sections of sod that were removed by the sod cutter on top and tamp down. The sections of sod should be watered to ensure root growth. The 6-in. section of pedestal below ground should be filled with gravel to ensure proper drainage.

Trenching—Multiple Cable

The procedures for multiple cable installations are the same as for single cable except that the trench is made wider.

Plowing—Single Cable Routes

To provide room for the vibrating plow, a 3-ft long trench has to be either machine- or hand-dug. Trenches should be dug on each side of the pedestal sites and deep enough to accept the plow blade. Obstacles such as fences require a trench to be dug on either side for the plow blade to be inserted. At this point the cable is unreeled according to one of the three methods described under "Trenching—Single Cable Routes." The cable is then placed along the plow route between the pedestals.

The plow is now positioned along the route and the blade lowered into the starting trench. The cable is then fed through the cable chute on the blade into the open trench. The vibrating plow then plows the cable into the next trench of the route. The cable is then removed from the chute and the plow is relocated to the next starting trench to continue the process. The cable is now fed into the pedestal location, and the trenches are backfilled, sodded, tamped, and watered.

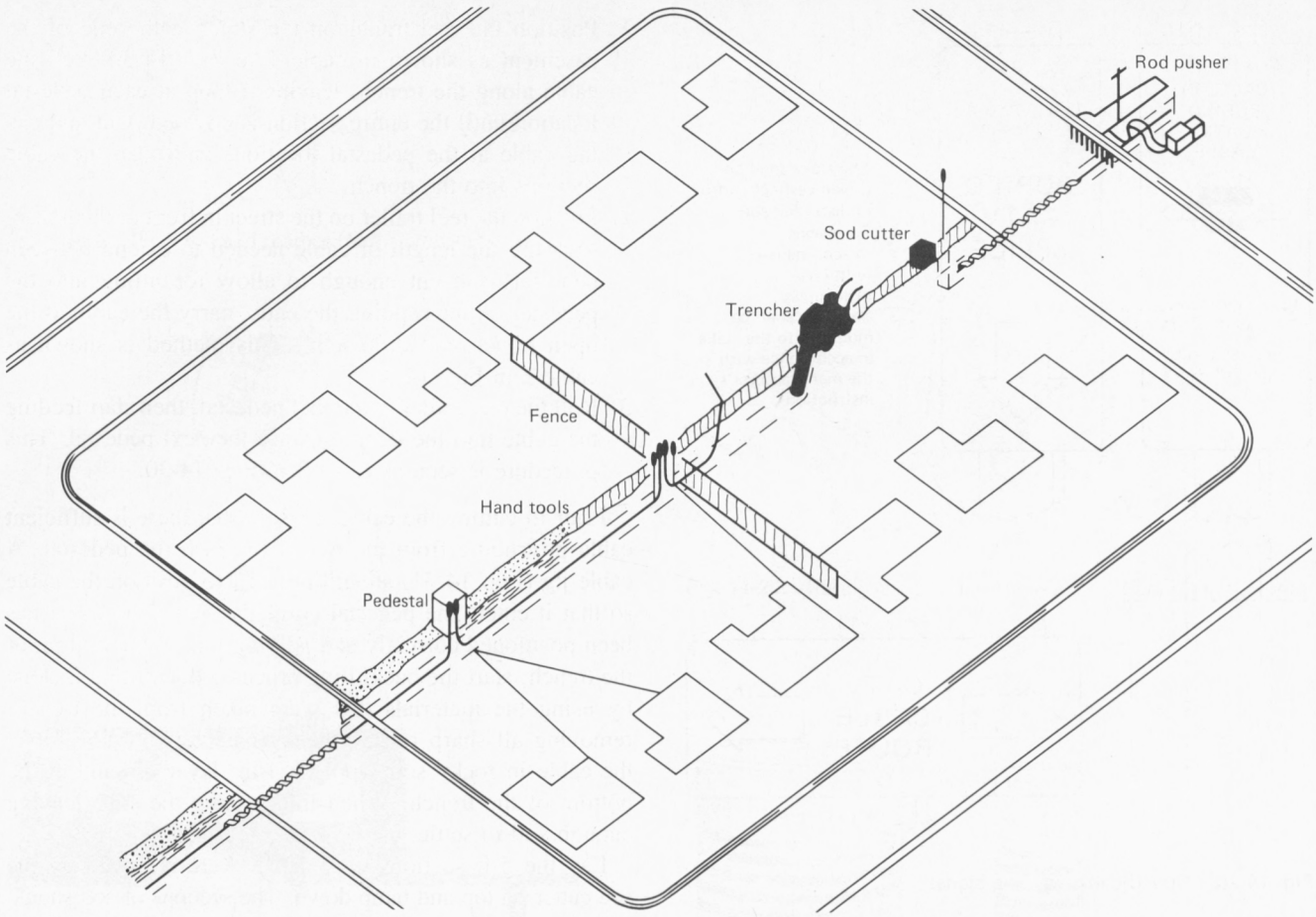


Fig. 14-29. Sod cutting and trenching operations (*M/A Com Comm-Scope*).

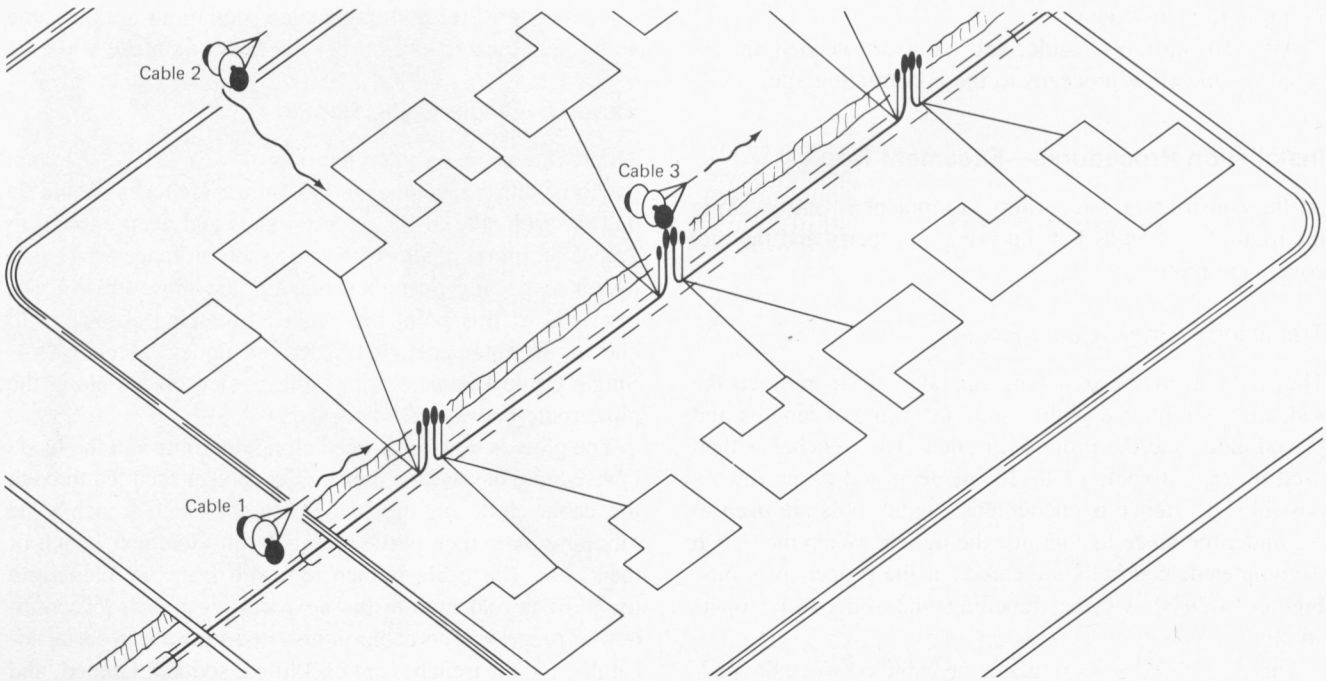


Fig. 14-30. Cable play-out methods (*M/A Com Comm-Scope*).

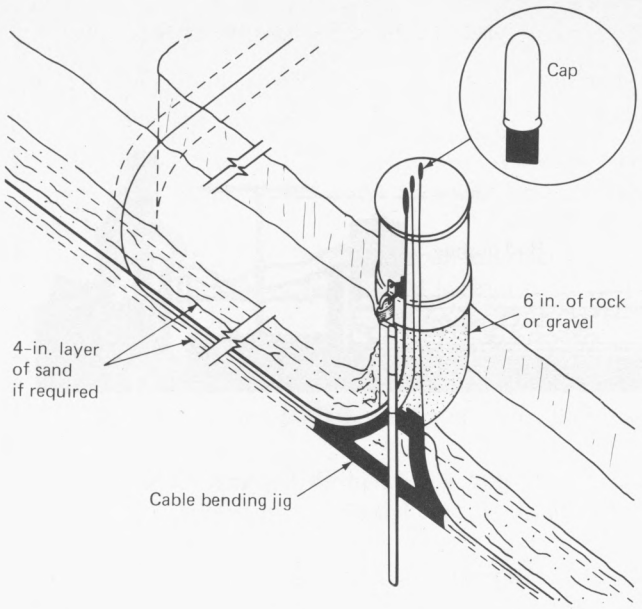


Fig. 14-31. Use of cable bending jig (*M/A Com Comm-Scope*).

Boring—Single Cable Routes

When driveways, sidewalks, and other short areas are encountered, boring pits are dug on each side for the rotating boring machine. The boring machine bores a hole under these areas large enough to allow the cable or conduit to pass through. The boring process can be seen in Fig. 14-32. When using the boring machine to make a longer hole for cable, follow these steps:

1. Attach a boring bit to a section of boring steel and connect enough sections together to reach the target area.
2. Place the bit and boring steel into the boring pit.
3. Place a target at the other side of the bore and dig a receiving pit.
4. Place the guide on the boring steel and align the guide and steel so that they point toward the target.
5. After leveling the steel, start the machine. As the bit pulls itself through the earth, keep the guide on the target and the boring steel level.
6. If the steel is deflected by an obstacle, use a pipe locater and dig another receiving pit.
7. Once the full length of boring steel has been used, replace the bit with either a reamer or a swivel-eye attachment. The reamer is used to enlarge the hole made by the boring bit. If the hole size is satisfactory, attach a swivel-eye grip and connect it to the end of the cable.
8. Start the machine and pull the steel, with cable attached, back through the hole.
9. Once the cable is pulled back to the boring pit, remove it from the grip and pull the balance through.

Boring—Streets

When streets or highways are encountered, a rod pusher is used. Figure 14-33 shows CATV construction workers using a rod pusher. The procedures for boring a hole with a rod pusher are similar to those used with the boring machine. The only exceptions are that push rods are assembled and pushed one by one and rod pushers do not rotate. As a section is added, it is leveled before being pushed.

When the cable is installed, the bore pits and receiving pits are backfilled the same as with trenches. Figure 14-34 shows the trenches and bore pits in a typical underground installation where streets, sidewalks, or driveways are encountered.

Installation Procedures—Street Cuts

When boring is not possible because of rocks or other conditions, the following procedures are followed:

1. Cut two grooves four inches apart across the street surface with a concrete saw.
2. Remove the material between the grooves by breaking it up with a jackhammer and removing it with hand tools.
3. Using a trencher, cut a trench to the desired depth.
4. Feed the cable into the trench and backfill to within 2 in. of the street surface (see Fig. 14-35).
5. After allowing the backfill to settle in the trench for 1 day, refill the remaining 2 in. with asphalt and compact with an asphalt compactor.

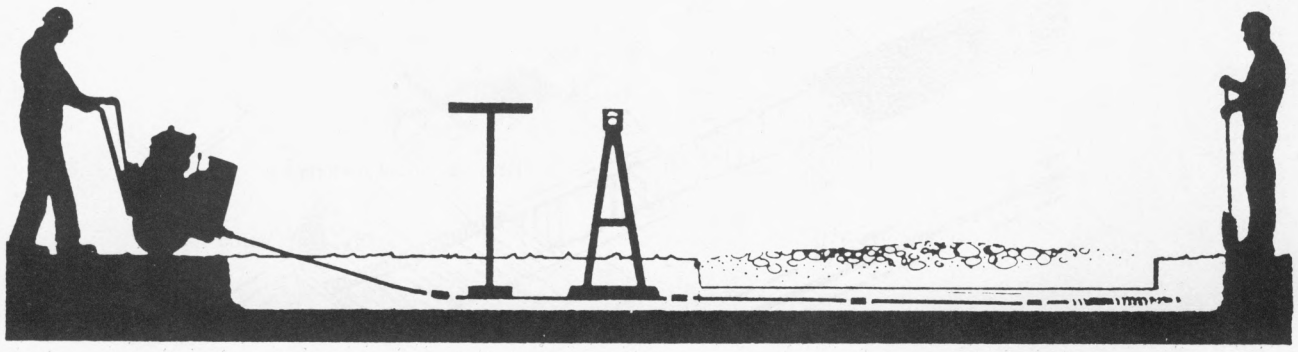


Fig. 14-32. Boring operation (*M/A Com Comm-Scope*).

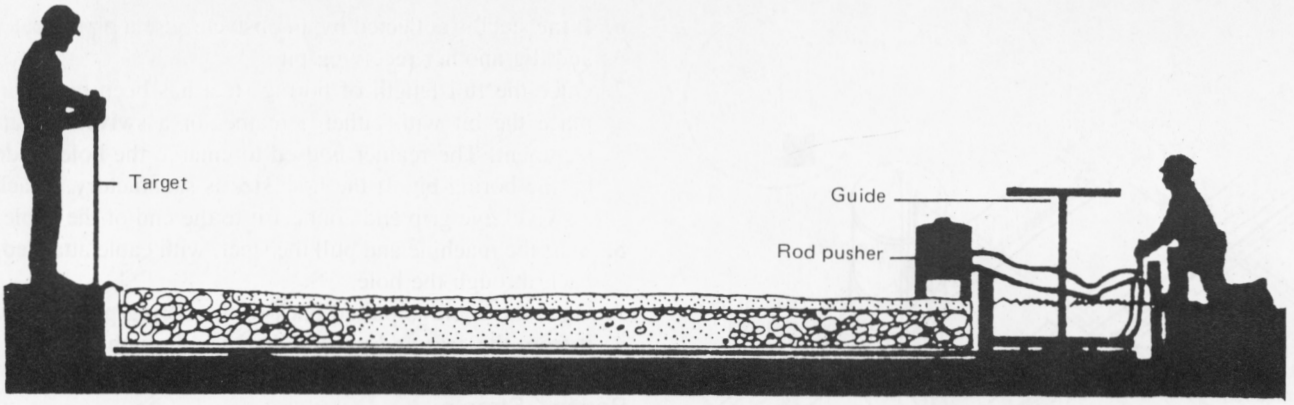


Fig. 14-33. Push rod operation (*M/A Com Comm-Scope*).

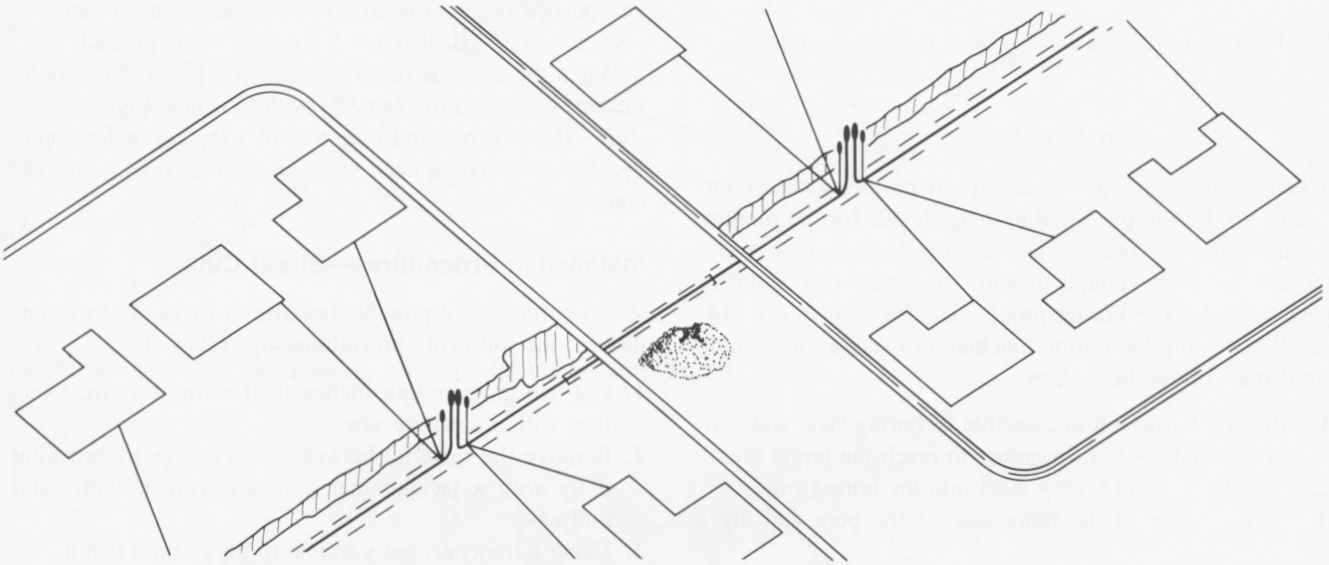


Fig. 14-34. Typical application of bore pits and trenching (*M/A Com Comm-Scope*).

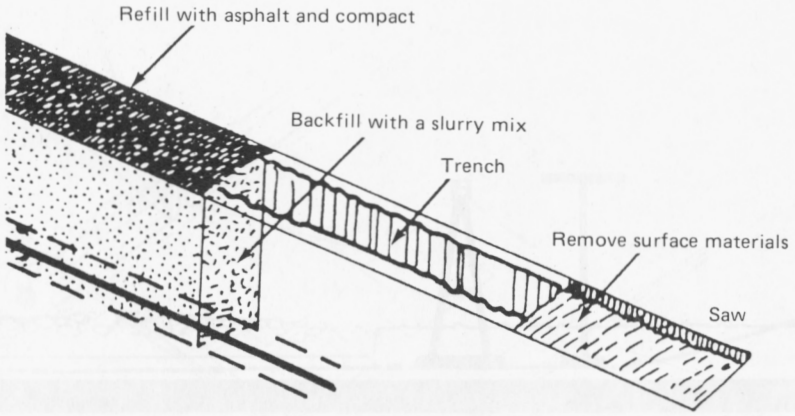


Fig. 14-35. Repairing a street cut (*M/A Com Comm-Scope*).

Installation Procedures—Street Routes

At a construction site where the cable is to be run along the street, the following procedures are used:

1. Using a sod cutter, cut 5-ft lengths of sod along the cable route. Roll up the lengths of sod and place along the trench.
2. Using a backhoe, cut bore pits at all street crossings, driveways, sidewalks, and pedestal locations.
3. Using the trencher, cut a trench joining all bore pits.
4. Using the boring machine, bore under driveways and sidewalks.
5. Using the rod pusher, push the push rods under the cross street.
6. Once the sod is removed, the trench dug, bore pits formed, and push rods placed, the coaxial cable is installed.
7. Set the pedestals.
8. Backfill all the trenches and replace the sod.

This procedure is followed, block by block, until the construction is complete. Figure 14-36 shows the activities on one block of the cable construction site.

Installation Procedures—Open-Area Routes

If the cable is to be installed in an open area *using trenches*, the following procedures are recommended:

1. Place an offset line along the proposed route for the trencher operator to follow.
2. Cut and remove the sod.
3. Dig the trench to the proper depth.
4. Place the cable into the trench and cut long enough to reach to the top of each pedestal.
5. Form the cable with a bending jig and cap the end.
6. Set the pedestal.
7. Backfill, tamp, and replace the sod.

If the cable is to be installed in an open area *by use of a vibrating plow*, first string an offset line along the plow route to guide the operator. Then dig starting and stopping trenches for the plow blade and chute at every pedestal location. Place the cable in the plow blade chute. Lower the plow into the starting trench and plow the cable to the pedestal. Then remove the cable and form it around the bending jig. Allow enough cable to reach to the top of the pedestal, then cut and cap. Insert the cable into the chute and plow to the next pedestal location. Repeat these procedures until the plow route is completed. Finally, set the pedestals, and backfill, tamp, and replace the sod.

Installation Procedures—Cable Pulling

When conduit is placed along the cable route, trench the route as outlined in "Installation Procedures—Easement Routes" given earlier. Place the conduit into the trench and spot backfill to hold it in place. Then blow a line through the conduit and pull the cable through. Finally, cut the cable, allowing adequate cable to reach the top of the pedestal and cap the ends.

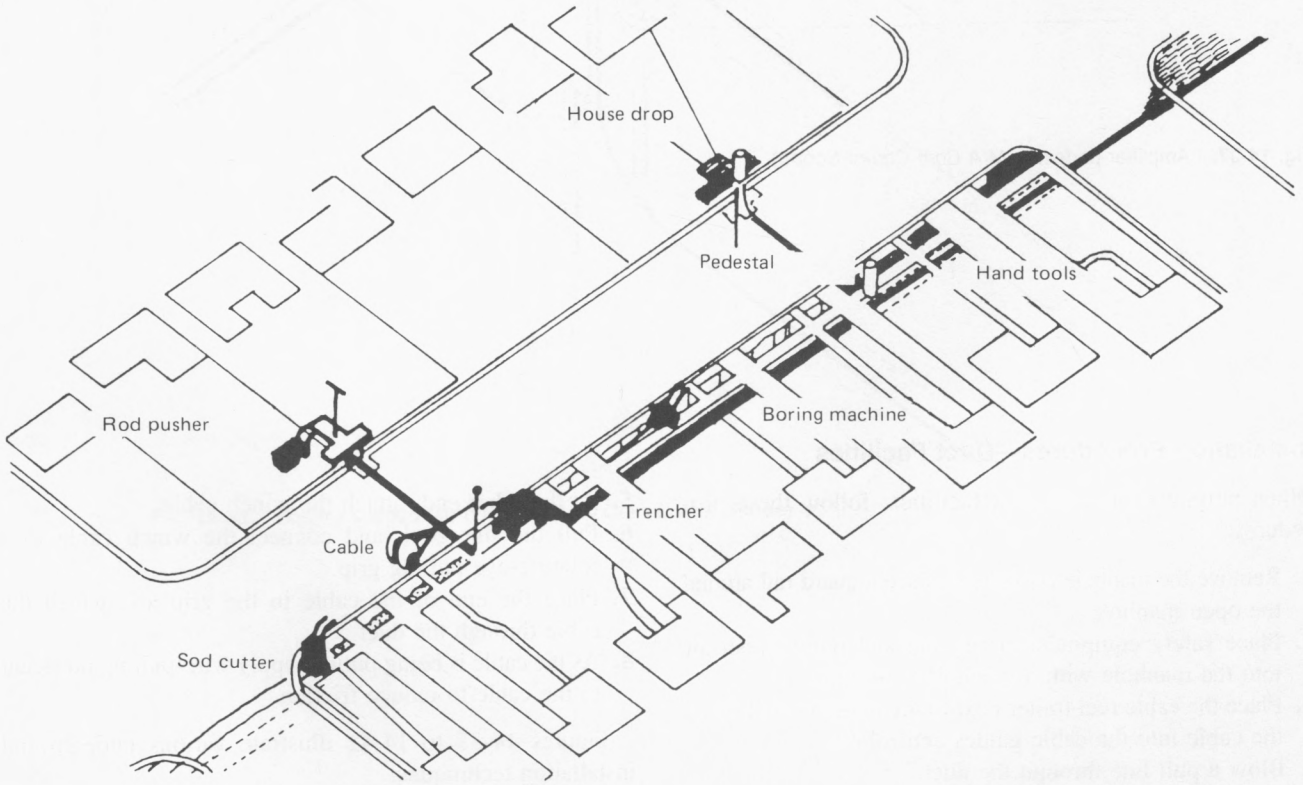


Fig. 14-36. Typical underground cable installation (*M/A Com Comm-Scope*).

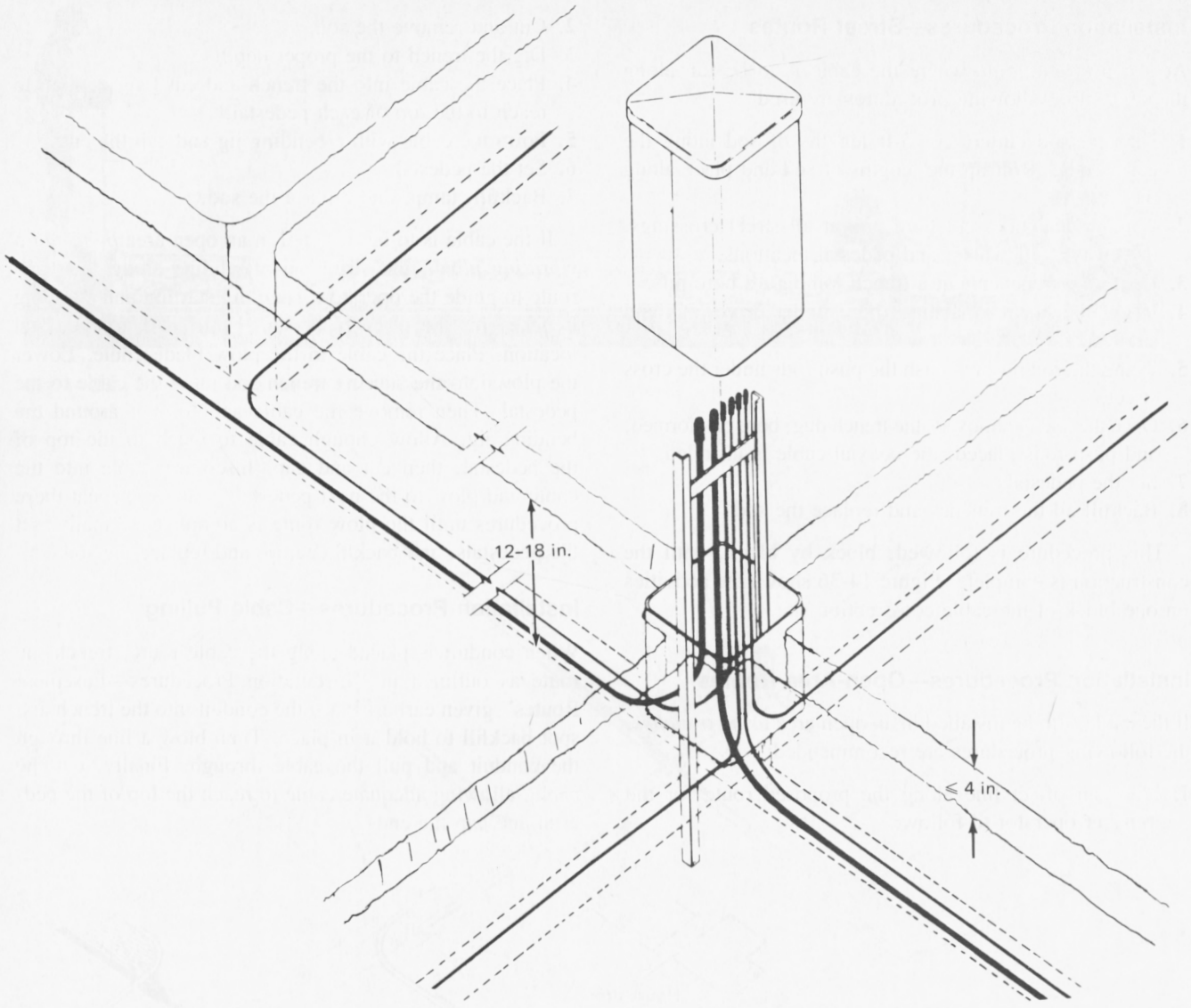


Fig. 14-37. Amplifier pedestal (*M/A Com Comm-Scope*).

Installation Procedures—Duct Facilities

When pulling cable into duct facilities, follow these procedures:

1. Remove the manhole covers and place a guard rail around the open manhole.
2. Place safety equipment at the site and pump fresh air into the manhole with a manhole ventilator.
3. Place the cable reel trailer next to the manhole and place the cable into the cable guides and rollers.
4. Blow a pull line through the duct.
5. At the other end, attach the winch cable.
6. Pull the line back and connect the winch cable to a rotating-eye pulling grip.
7. Place the end of the cable in the grip and winch the cable through the duct.
8. As the cable is being pulled, apply wire-pulling lubricant to the cable to reduce friction.

Figures 14-37 to 14-42 illustrate various underground installation techniques.

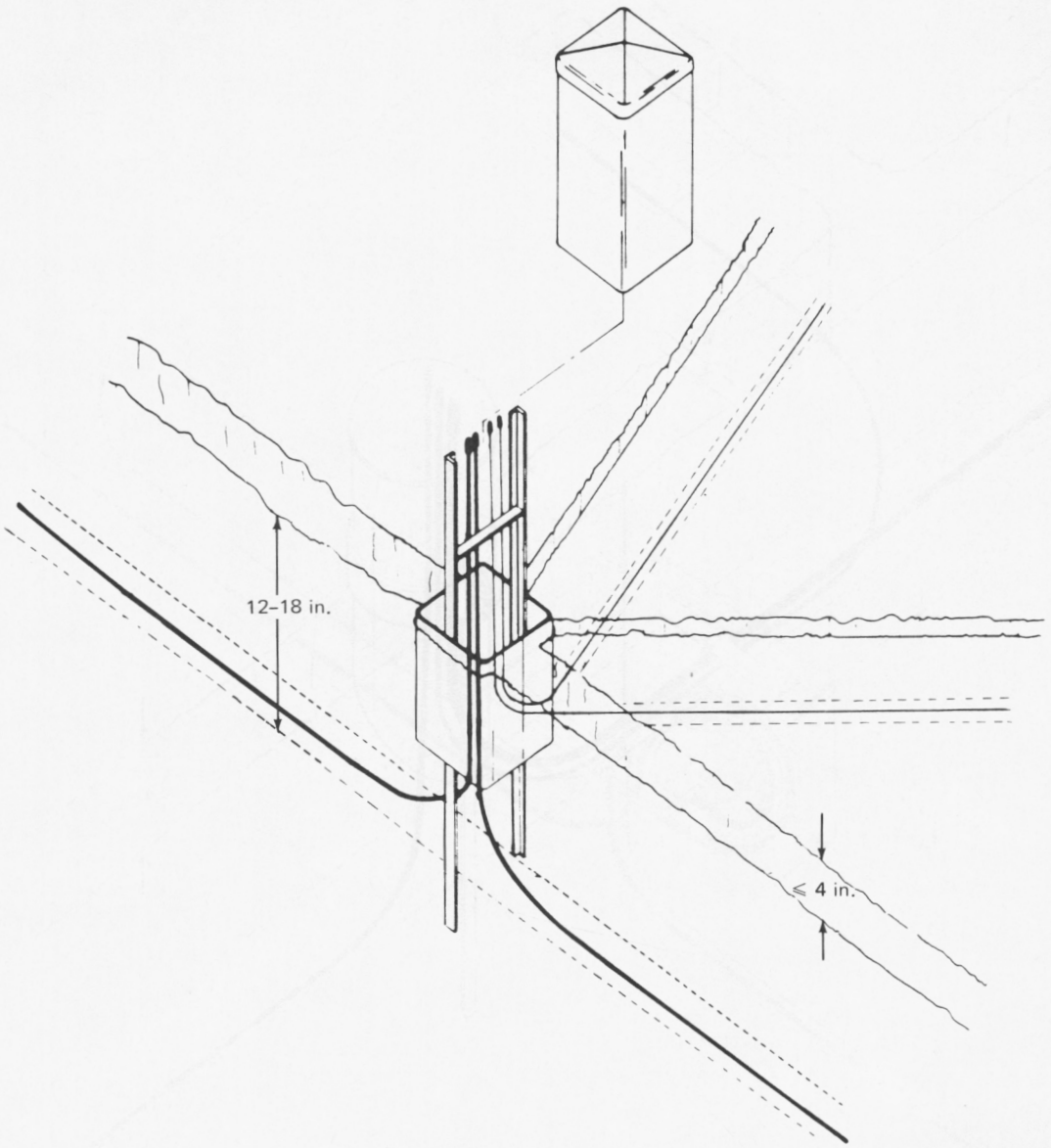


Fig. 14-38. Square-shaped tap pedestal (*M/A Com Comm-Scope*).

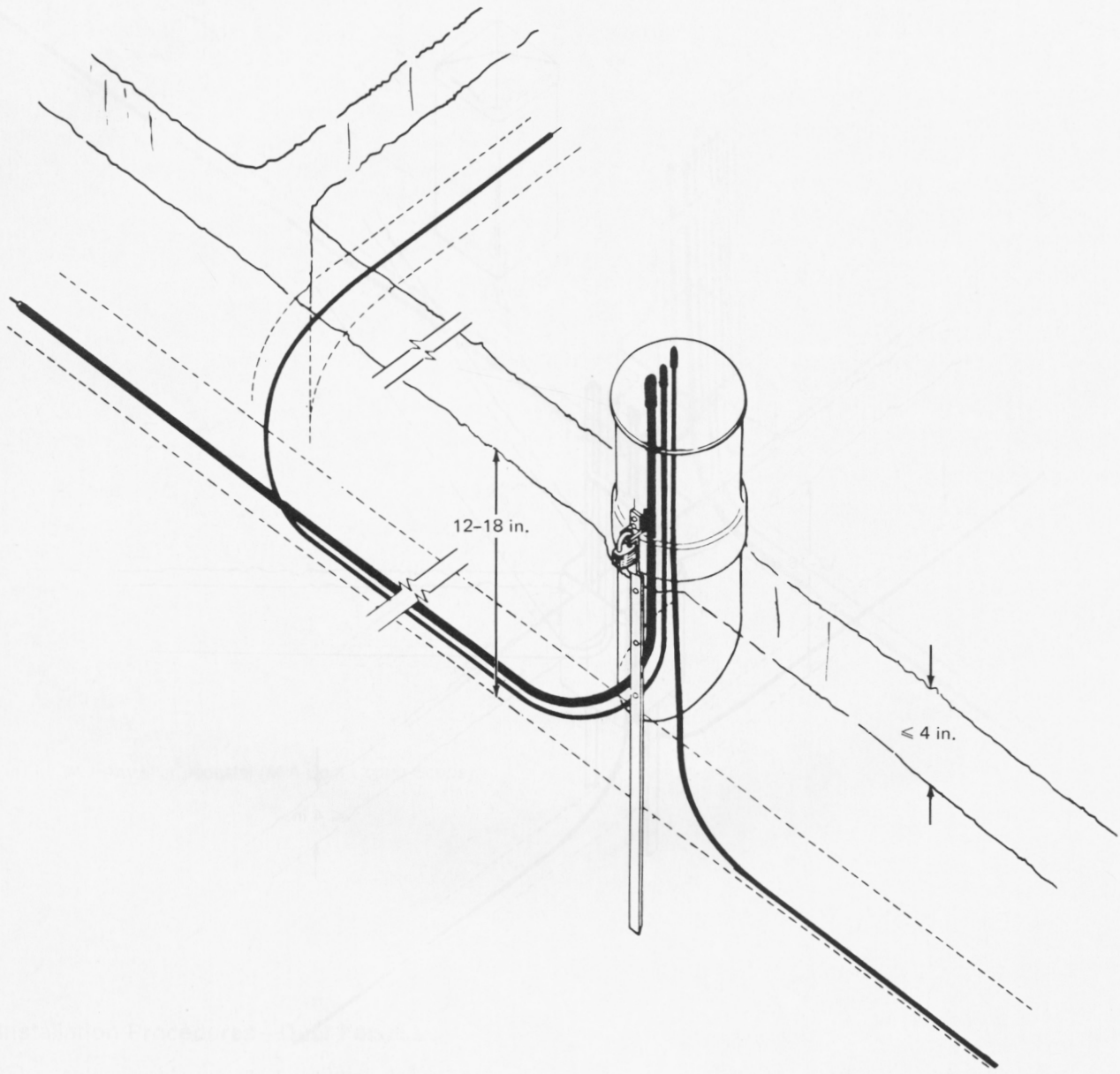


Fig. 14-39. Round tap pedestal (*M/A Com Comm-Scope*).

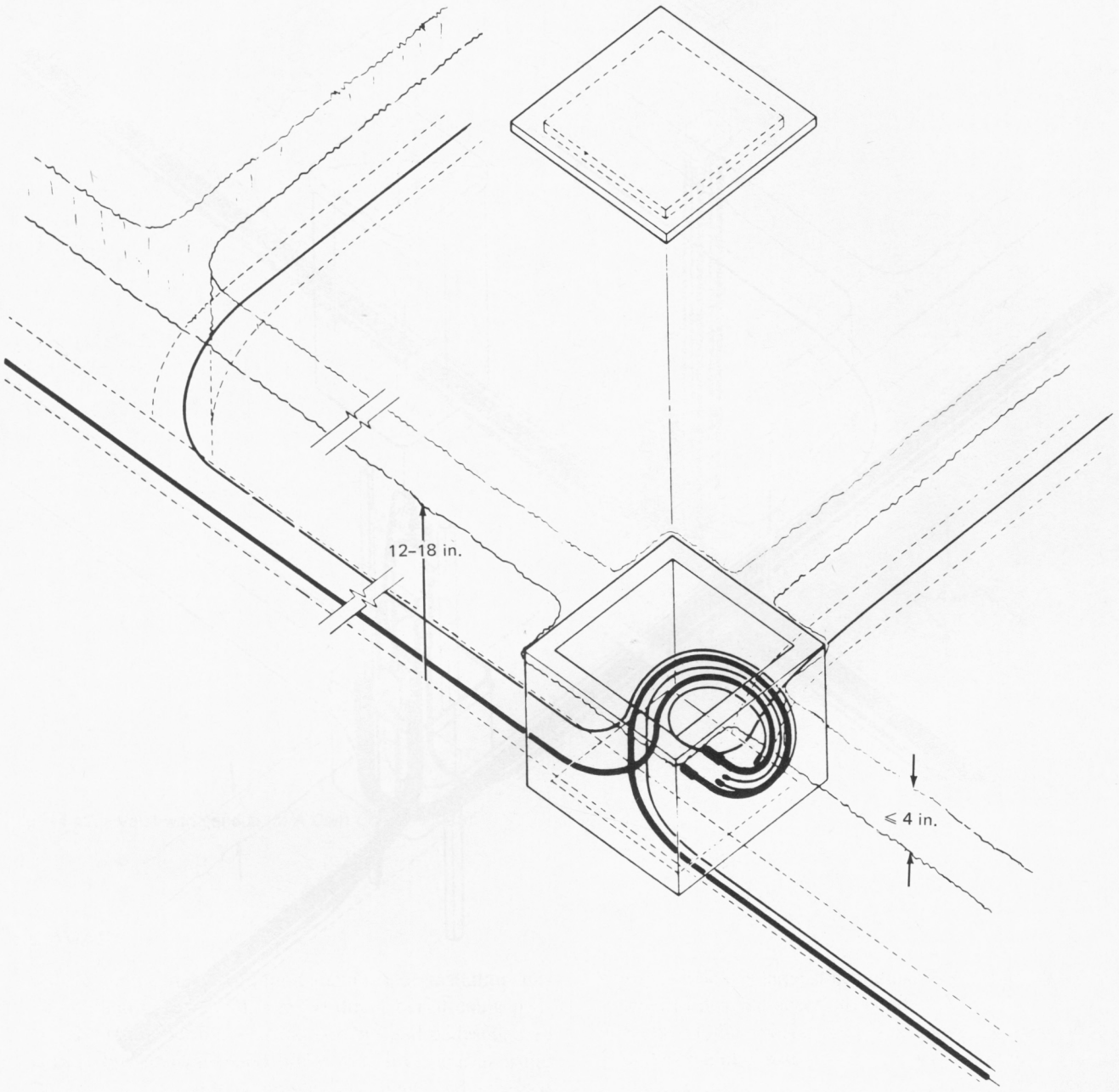


Fig. 14-40. Vault installation (*M/A Com Comm-Scope*).

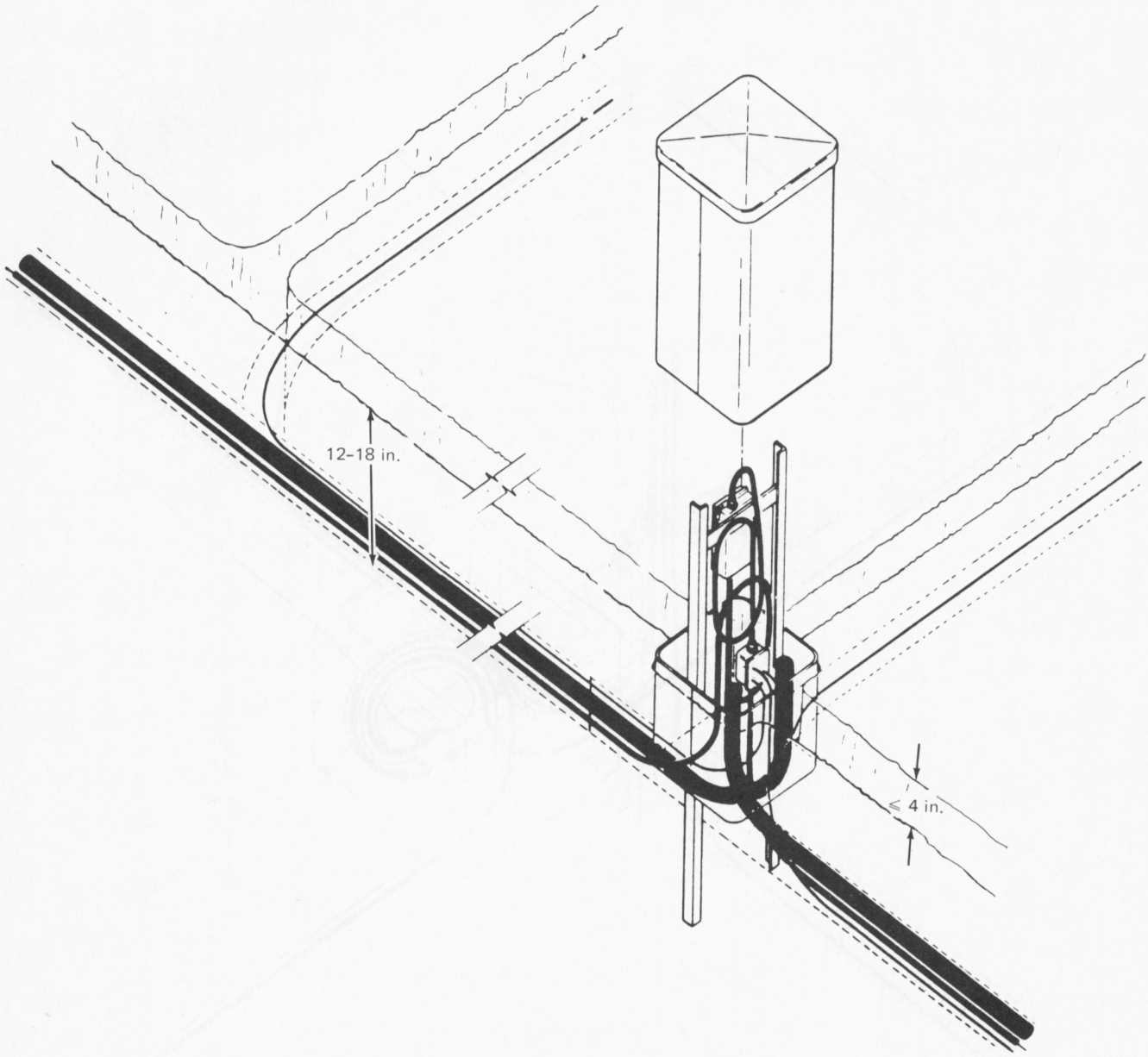


Fig. 14-41. Amplifier splicing pedestal using conduit (*M/A Com Comm-Scope*).

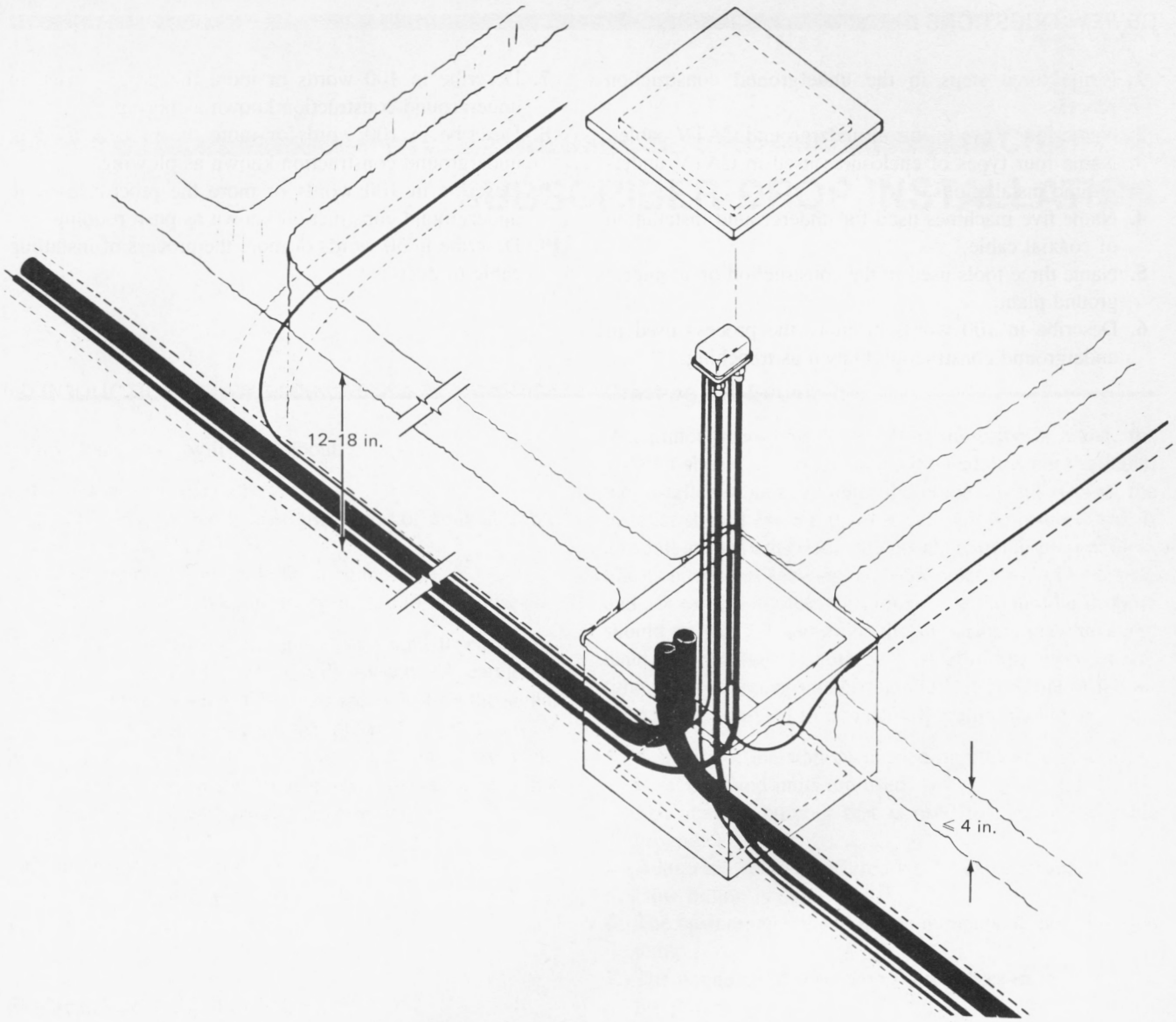


Fig. 14-42. Vault with conduit (*M/A Com Comm-Scope*).

SUMMARY

1. Some of the more common methods of installing underground CATV cable are (*a*) direct burial using pedestals, (*b*) direct burial using conduit and pedestals, (*c*) direct burial using hand holes, (*d*) direct burial using vaults, and (*e*) cable being placed in ducts and accessed by manholes.
2. A pedestal is a small housing, placed above ground level, that contains active or passive CATV equipment.
3. Conduit consists of hollow tubes of metal or plastic that protects cable from punctures and mechanical stresses.
4. A hand hole is a small housing that is placed below ground level to house cable and CATV equipment.
5. Vaults are larger housings that are placed below ground level to house cable and CATV equipment.
6. A manhole is a large structure that is placed below ground level to provide access to conduit or ducts.
7. Some of the specialized tools and equipment used in underground construction are (*a*) sod cutters; (*b*) trenchers; (*c*) vibrating plows; (*d*) cable chutes for vibrating plows; (*e*) backhoes; (*f*) trailers; (*g*) boring machines and steels; (*h*) rod pushers, (*i*) push rods, reamers, and bits; (*j*) jackhammer and compressor; (*k*) concrete saws; (*l*) blowers, pulling line, and line carriers; (*m*) wire-pulling lubricants; and (*n*) rakes, shovels, and hoses.
8. Coaxial cable is placed underground by one or more of the following procedures: (*a*) trenching, (*b*) plowing, (*c*) boring, and (*d*) placing in conduit or ducts.

REVIEW QUESTIONS

1. Name three steps in the underground construction process.
2. Name four ways to install underground CATV cable.
3. Name four types of enclosures used in CATV underground installations.
4. Name five machines used for underground installation of coaxial cable.
5. Name three tools used in the construction of an underground plant.
6. Describe in 100 words or more the process used in underground construction known as trenching.
7. Describe in 100 words or more the process used in underground construction known as boring.
8. Describe in 100 words or more the process used in underground construction known as plowing.
9. Describe in 100 words or more the process used in underground construction known as push rodding.
10. Describe in 50 words or more the process of installing cable in ducts.

15 CHAPTER

SUBSCRIBER DROP INSTALLATION

INTRODUCTION

In this chapter you will learn about:

1. Guidelines for installers
2. Tools, devices, hardware, and types of coaxial cable used in subscriber drops
3. Preparation of drop cable for a connector
4. Installation of drop cable from the tap to the house

Delivery of a sharp picture and clear sound to each subscriber is the goal of every CATV system. A carelessly done installation can not only interrupt or destroy the signal up to that point, but can also disrupt service for all CATV subscribers connected to that feeder. Understandably, then, the subscriber drop installation is the most important link in the signal chain and should be done very carefully.

The job of the installer is to bring a length of coaxial cable from the tap into the subscriber's home. This cable must take the most direct route possible, be inconspicuous, and be properly grounded.

GUIDELINES FOR INSTALLERS

There are certain general rules for procedure and behavior to be followed by the installer when entering a subscriber's home and establishing cable service.

Prior to Installation

After making sure that all the tools and supplies are in the truck, the installer should check the work orders for any special instructions or times and, if permitted, call the subscriber in advance to verify addresses, determine the nature of the installation, and give an approximate time of arrival.

On arriving at the subscriber's home, the installer's van or truck should be parked on the street or in an alley, never in the subscriber's driveway. The flashers should then be turned on and a safety cone placed at the front and rear of the vehicle. On approaching the subscriber's home, the installer should determine the method to use in running the drop. Generally, the drop cable will enter the home at the same point where power and telephone service drops are located.

Greeting the Subscriber

If a minor opens the door of the subscriber's home, the installer should ask for an adult. If an adult is not available, the installer *should not* enter the home. If this occurs, the installer should explain that the call will be rescheduled. If an adult answers the door, the installer should present identification, such as showing the work order for CATV service, and ask to be admitted. Once inside the home, the installer should answer any questions the subscribers may have and hand out company literature. Answering questions at this time will prevent misunderstandings later. Some of the information contained in company literature includes:

1. A listing of the stations carried on the cable system
2. How the hand units are used
3. The channel number that is used to receive the cable programs
4. Additional services offered by the cable system
5. How billing is done
6. The business hours and phone numbers of the cable system
7. The phone number to report difficulties in receiving cable programs

When all questions have been answered to the subscriber's satisfaction, the installer should ask to be shown the set(s) that are to be connected to the cable service. The installer should then ask the subscriber to turn the set(s) on and tune in all the channels. The condition of the reception should be noted and any problems pointed out to the subscriber. A set that will not show ''off-air'' signals properly will generally be unable to satisfactorily handle cable signals, either. If informed of the problem by the installer at this time, the subscriber usually will be less critical after cable is installed. The installer should then explain the proposed route for installing the cable and incorporate any suggestions made by the subscriber, if possible.

The Installer's Conduct in the Subscriber's Home

The installer's behavior in the subscriber's home is a reflection of not only the installer, but the cable company as well. In many instances, the impression made by the installer can determine whether the subscriber will be satisfied

or dissatisfied with the cable service. The installer is the public relations representative for the cable company and, as such, must act the part. Some of the guidelines to be followed by installers in a subscriber's home are:

1. Act in a professional manner at all times.
2. Always be courteous.
3. *Always* explain exactly what will be done to install the cable. Explain where holes will be drilled, how the cable will be run, and where splitters will be located.
4. Never smoke in a subscriber's home.
5. Do not track in dirt or mud.
6. Avoid moving anything. It is better to have the subscriber move furniture or other items.
7. Never place tools on the subscriber's furniture or rug. Bring a cloth to lay the tools on.
8. Do not converse unnecessarily with the subscriber. Answer questions the subscriber may have, but do not initiate any idle chatter. If the subscriber is interested in watching, you may explain the procedure.
9. Do not recommend or condemn any TV manufacturer or TV service company.
10. Do not use the subscriber's bathroom facilities or accept water, or other beverages, food, or assistance from the subscriber.
11. Do not make adjustments or repairs on subscriber's TV receivers.
12. Demonstrate the operation of the converter and the hand unit.
13. Advise any subscriber who becomes dissatisfied with the installation for any reason while it is in progress to speak to your supervisor; never engage in an argument.
14. When finished, pack up your equipment and clean up after yourself.
15. If you are to collect moneys, present the bill with the subscriber's copy of the work order. *Always* leave a receipt.
16. On leaving, express gratitude for the subscriber's interest and patience during the installation. The impression you leave may be the impression the subscriber has of the overall company.

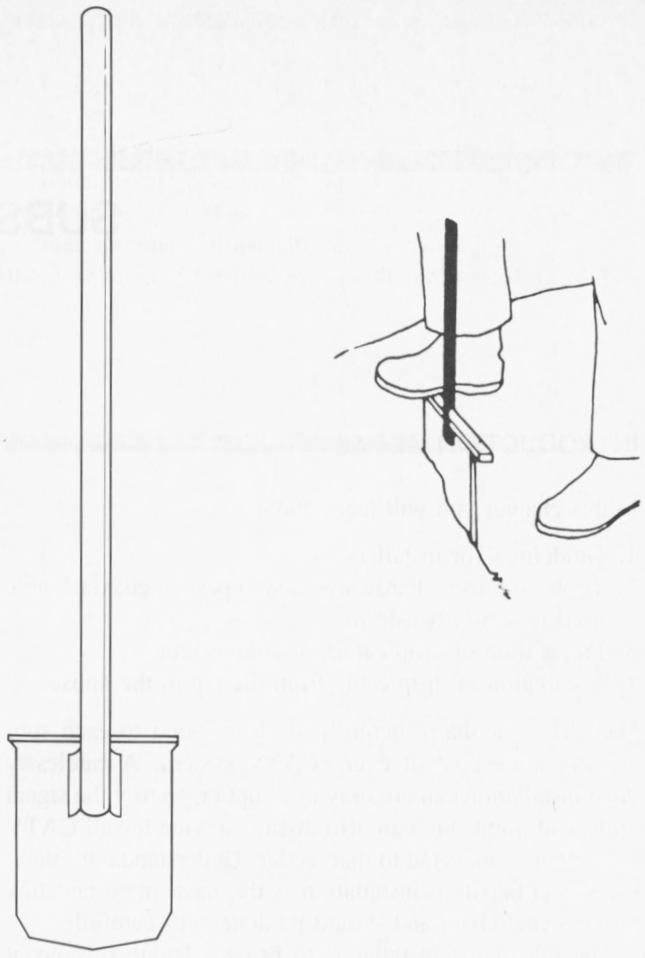


Fig. 15-1. Trenching tool (*Lemco Tool Corp.*).

SUBSCRIBER DROP TOOLS AND DEVICES

Because the cable used for making subscriber drops is different from that used in the distribution system, the devices, tools, and connectors are also different.

Some of the more common tools and devices used by installers of subscriber drop cable are:

- *A trenching tool*. This tool is used to make a trench for the subscriber drop cable that extends from the pedestal to the subscriber's home. The trenching tool has a straight blade that allows the installer to dig the trench with a minimum of effort. Figure 15-1 shows the trenching tool and illustrates its use.

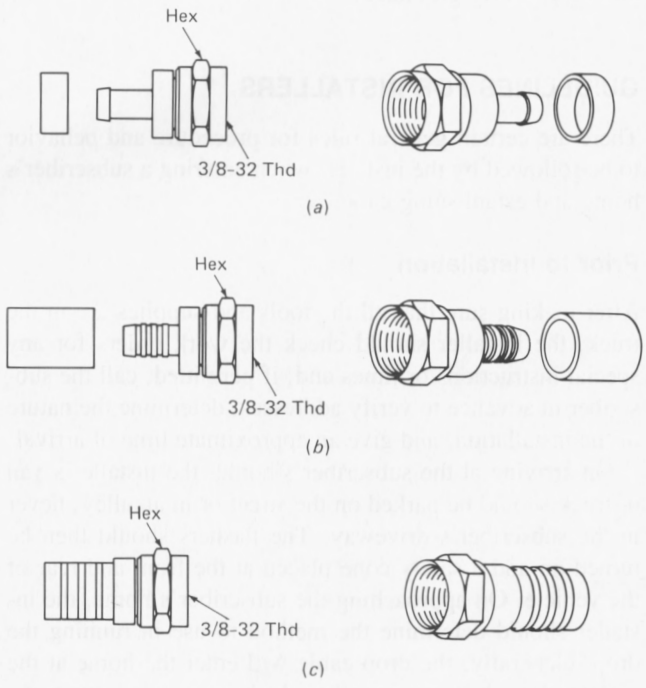


Fig. 15-2. Drop-cable F connectors (*Anixter Bros., Inc.*).

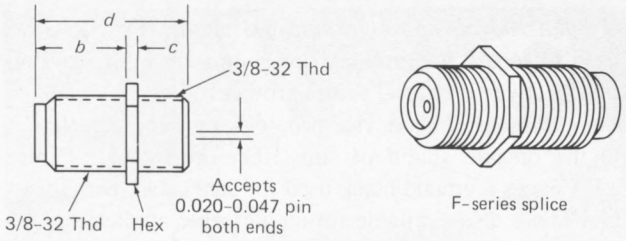


Fig. 15-3. Splice connector (F-81) (*Anixter Bros., Inc.*).

- *Drop-cable connectors*. Figure 15-2 shows the three styles of connectors commonly used on subscriber drop cables. Figures 15-2*a* and 15-2*b* show connectors with separate crimp rings, while Fig. 15-2*c* shows the crimp ring built onto the barrel of the connector. The crimp ring is used to secure the connector to the cable. These connectors are referred to as "F connectors," and their installation is discussed later.
- *Drop-cable splice connector*. This connector is a female adapter that allows two cables to be joined together. The device shown in Fig. 15-3 will accept the connectors from either of the two more commonly used subscriber cables. This device is known as an "F-81," or "barrel connector."
- *Drop-cable preparation tool*. Figure 15-4 shows a tool used to strip drop cable so that a connector may be installed. This tool cuts the jacket, shield, and dielectric to the proper lengths all in one operation.
- *Connector tool (crimper)*. This tool is used to crimp (squeeze) the crimp rings shown in Fig. 15-2. The crimping tool shown in Fig. 15-5 is designed to crimp three different sizes of crimp rings.
- *Cable caddie*. Figure 15-6 shows a carrier for subscriber drop cable. The caddie can be either left stationary and the cable pulled from it or carried and the cable allowed to play out.
- *Ground rod*. This is a ⅜-in.-diameter copper-coated steel rod used to ground the drop-cable shield. Ground rods range in length from 4 to 8 ft. Figure 15-7 shows the type of ground rod used in CATV installations.

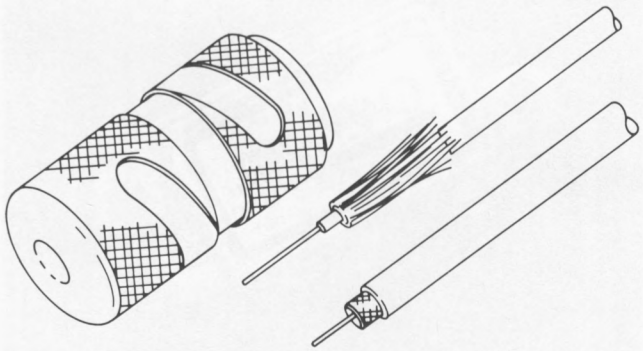


Fig. 15-4. Drop-cable preparation tool (*Anixter Bros., Inc.*).

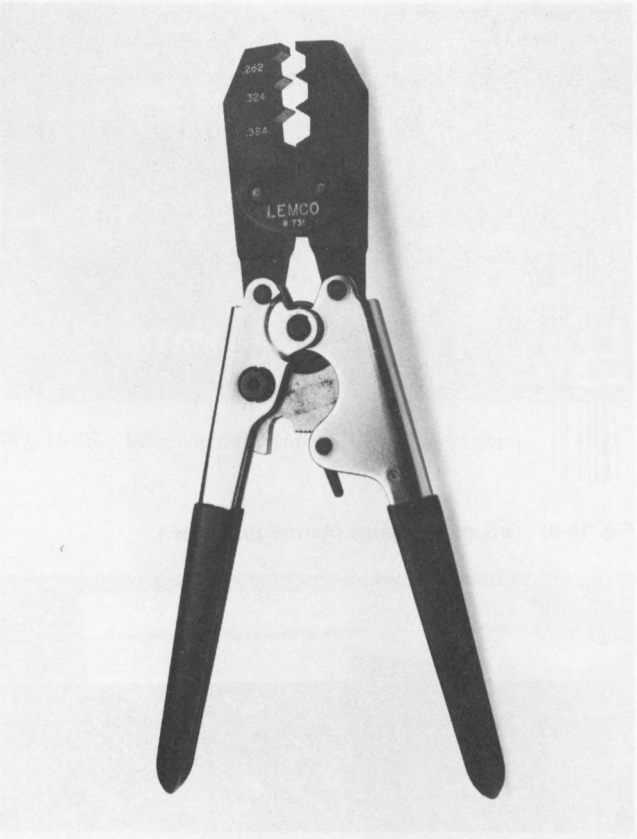


Fig. 15-5. Drop-cable connector tool (*Lemco Tool Corp.*).

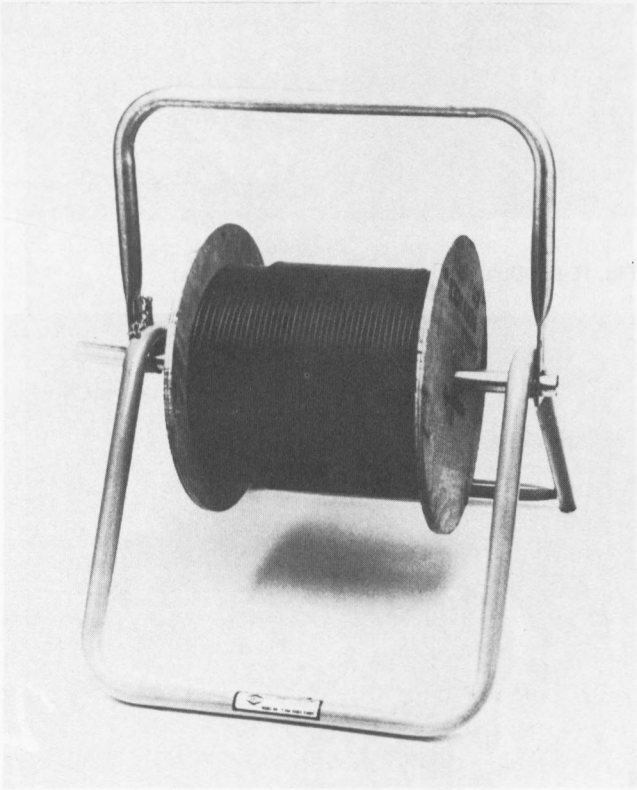


Fig. 15-6. Drop-cable reel caddie (*Lemco Tool Corp.*).

Fig. 15-7. Ground rod (*CWY Electronics*).

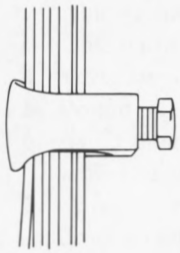


Fig. 15-8. Ground rod clamp (*Anixter Bros., Inc.*).

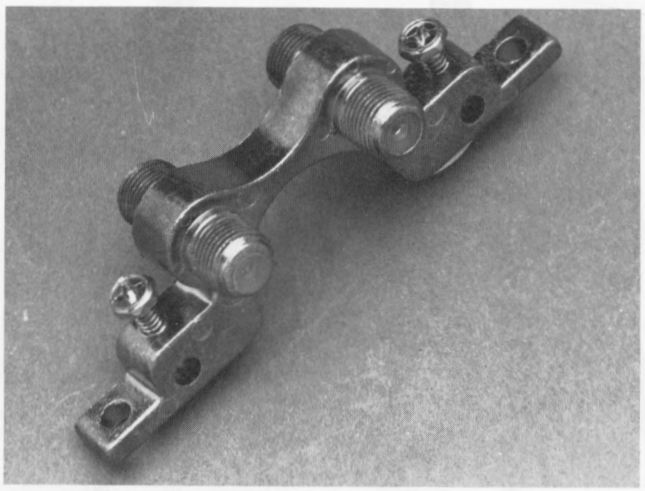


Fig. 15-9. Dual ground block (*CWY Electronics*).

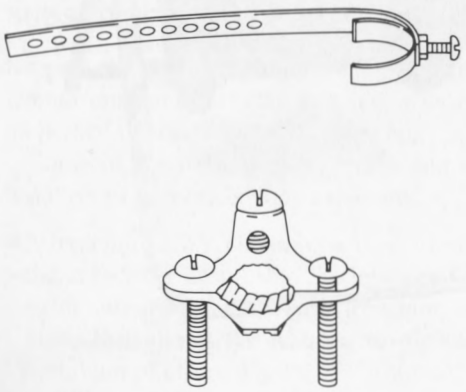


Fig. 15-10. Ground strap and clamp (*Anixter Bros., Inc.* and *CWY Electronics*).

- *Ground rod clamp*. A ground rod clamp (Fig. 15-8) is used to secure the ground wire coming from the ground block (covered below) to the ground rod.
- *Ground block*. This device provides a ground connection to the outside shield of subscriber drop cable. Figure 15-9 shows a ground block used for dual cable, but ground blocks are also available for single cable applications.
- *Grounding straps and clamps*. These devices provide a connection between the ground block and the cold-water pipe of the subscriber's residence. Figure 15-10 shows both a ground strap and a ground clamp.
- *Two-way splitter*. The two-way splitter shown in Fig. 15-11 is used to split the incoming signal into two paths. Splitters are used whenever more than one device (TV, radio, VCR, etc.) is to be supplied with signal. Both output ports supply signals that are 3.5 dB lower than the input signal.
- *Three-way splitter*. Figure 15-12 shows a splitter that supplies signal to three devices. This splitter attenuates the signal by 5.5 dB at all three ports.
- *Four-way splitter*. The four-way splitter shown in Fig. 15-13 is used to provide signal to four devices. A four-way splitter has four ports, each of which attenuates the signal by 7.0 dB.
- *Coaxial cable switch*. A coaxial cable switch is used on cable systems that use two seperate cables to bring signals to the subscriber. Figure 15-14 shows a coaxial cable switch, sometimes called an *AB switch*.
- *Matching transformer*. Figure 15-15 shows three styles of matching transformers used in CATV. A matching transformer is used to match the 75-Ω coaxial cable to the 300-Ω terminals on the TV set.
- *Apartment box*. This is a steel enclosure used to house taps, splitters, and amplifiers used within an apartment house. Figure 15-16 shows an apartment box enclosure.
- *House hook*. The house hook (Fig. 15-17) is screwed into the siding of the home to anchor the cable coming from the tap.

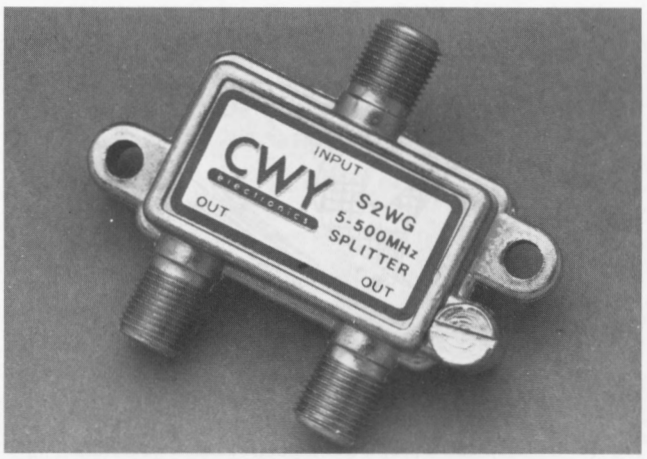


Fig. 15-11. Two-way splitter (*CWY Electronics*).

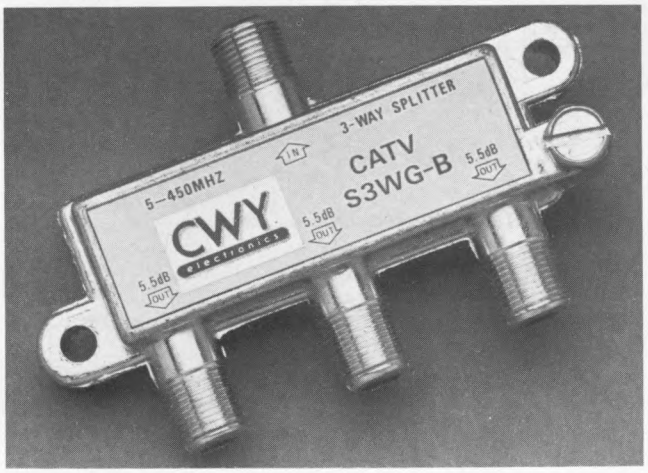


Fig. 15-12. Three-way splitter (*CWY Electronics*).

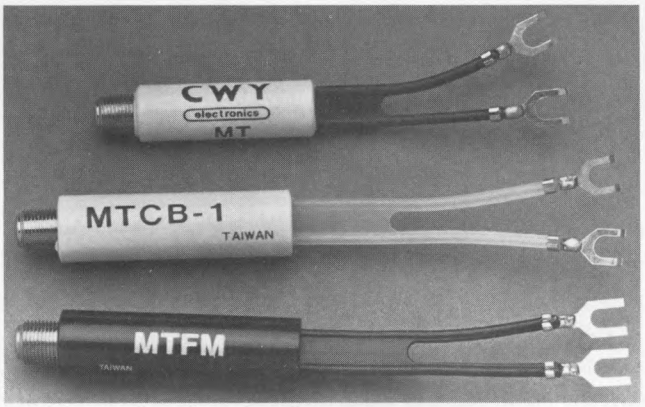


Fig. 15-15. Matching transformers (*CWY Electronics*).

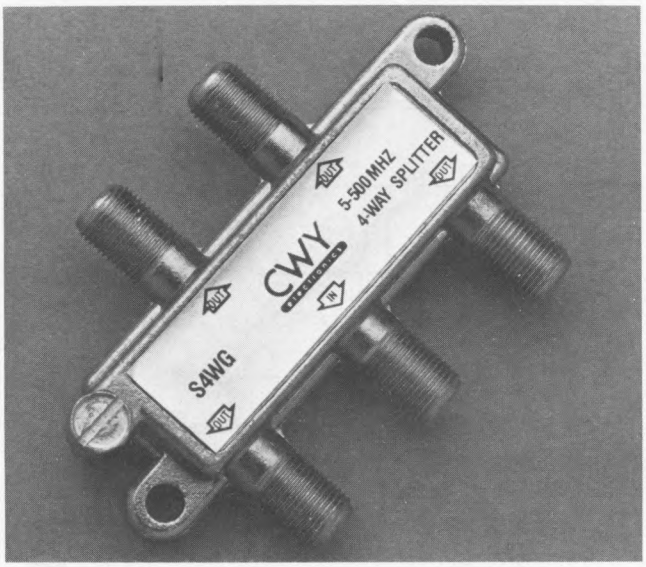


Fig. 15-13. Four-way splitter (*CWY Electronics*).

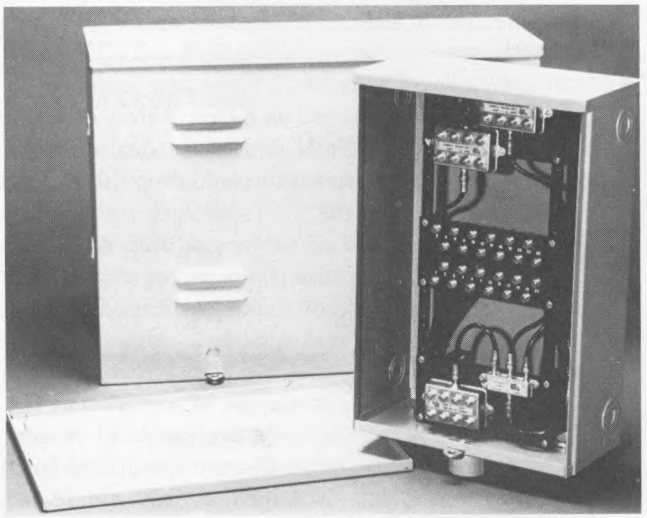


Fig. 15-16. Apartment box (*CWY Electronics*).

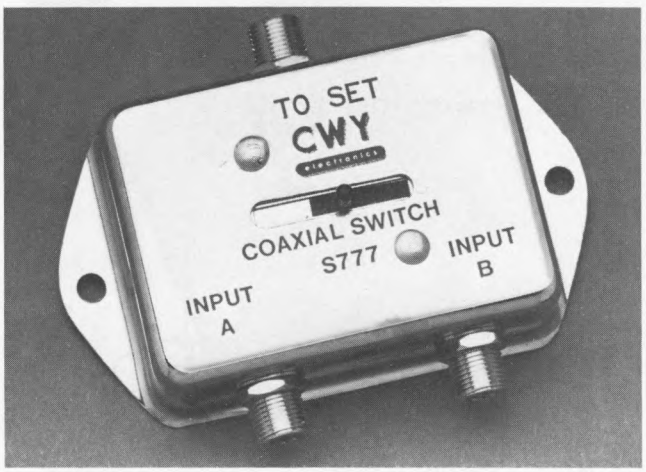


Fig. 15-14. Coaxial cable switch (*CWY Electronics*).

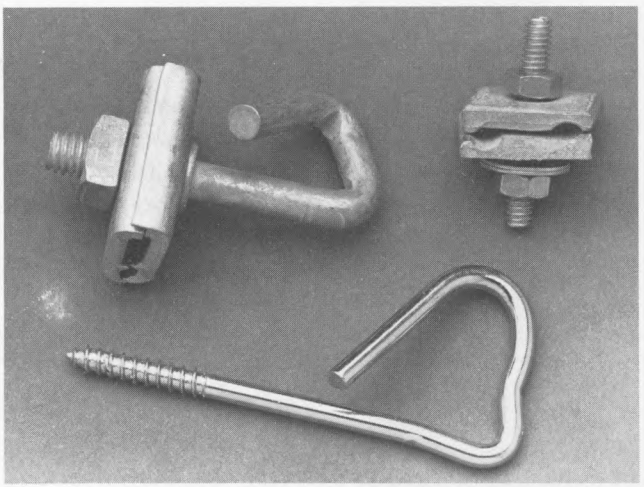


Fig. 15-17. Span clamp, lashing clamp, and house hook (*CWY Electronics*).

- *Span clamp*. A span clamp such as the one shown in Fig. 15-17 is used to hold drop cable at the tap location. Span clamps clamp onto the strand cable and provide a hook for drop-cable grips to fit into.
- *Drive ring*. A drive ring serves the same purpose as a house hook except that it is driven in with a hammer, not screwed. Figure 15-18 shows a drive ring used for subscriber drop cable.
- *Drop-cable grip*. A drop-cable grip is used to hold unmessengered subscriber drop cable in both house hooks and span clamps. Figure 15-19 shows a preformed drop-cable grip (dead-end).
- *Drop-cable clamp*. This device (Fig. 15-20) is used to hold drop cable against a subscriber's residence. The clamp can be either nailed or screwed into place.
- *Siding clips*. These are devices that fit under house siding and are used to hold drop cable against a subscriber's residence. Two styles of clips are available, depending on the direction of the cable. Both styles are shown in Fig. 15-21.
- *Plastic cable clips*. Figure 15-22 shows four sizes of cable clips. The first three are used on different sizes of cable. The type shown on the right is used for dual cable installations. Cable clips are used to hold drop cable to the side of a subscriber's home.
- *Stapler*. Another method of securing a drop cable to a subscriber's residence is through the use of staples. Figure 15-23 shows the type of stapling gun used to drive metal staples into siding and shingles.
- *Feed-through bushing*. This is a nylon or plastic insert that fits into a hole drilled in the side of a residence. The bushing gives a neat appearance and helps to prevent water from entering the home through the drilled hole. Feed-through bushings are available in both single and dual cable sizes (Fig. 15-24) and in black and beige.
- *Connector locks*. Figure 15-25 shows a connector locking device that prevents the removal of a drop-cable connector from a tap. Figure 15-26 shows how these locks are installed. Devices such as these must be destroyed in order to be removed. They are available in six different colors to signify the type of service given to the subscriber.
- *Connector cover*. This is a unique alternative to the use of heat-shrinkable materials on drop-cable splice connectors. These units are reusable, watertight, and protect the splice from the elements. Figure 15-27 shows a connector cover both assembled and open for inspection.
- *Wall plates*. This device is used to cover the exit hole made when a subscriber drop cable is brought out through the wall of a home. Wall plates are made of metal or plastic, measure 2¾ × 4½ in., and contain either one or two F-81 splice connectors. One side of the splice connector accommodates the drop cable. The other side is either terminated or connected to a TV set or converter through a short length of drop cable. Wall plates are generally fastened to a wall with screws and anchors.

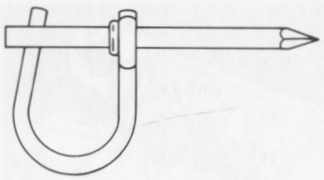


Fig. 15-18. Drive hook (*Anixter Bros., Inc.*).

Fig. 15-19. Drop-cable grip (dead-end) (*Anixter Bros., Inc.*).

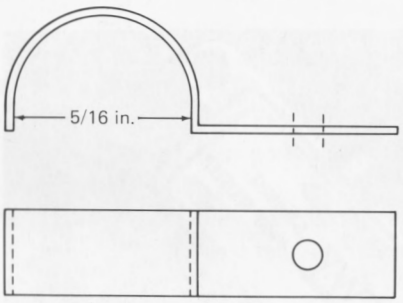


Fig. 15-20. Drop-cable clamp.

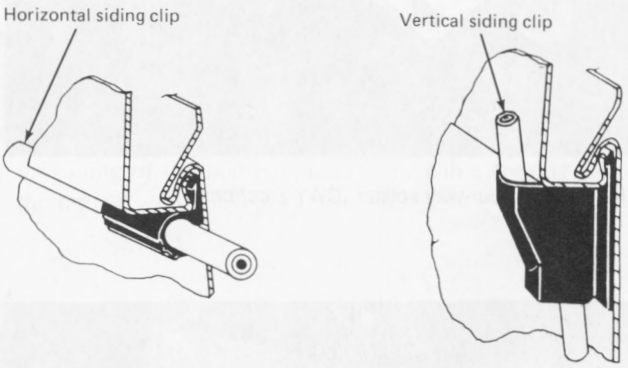


Fig. 15-21. Siding clips (*CWY Electronics*).

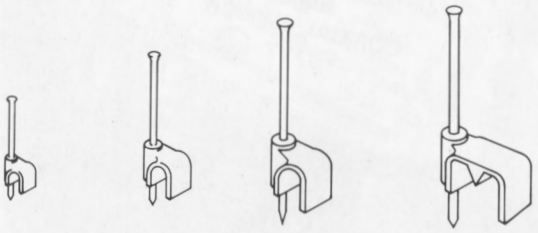


Fig. 15-22. Cable clips (*Anixter Bros., Inc.*).

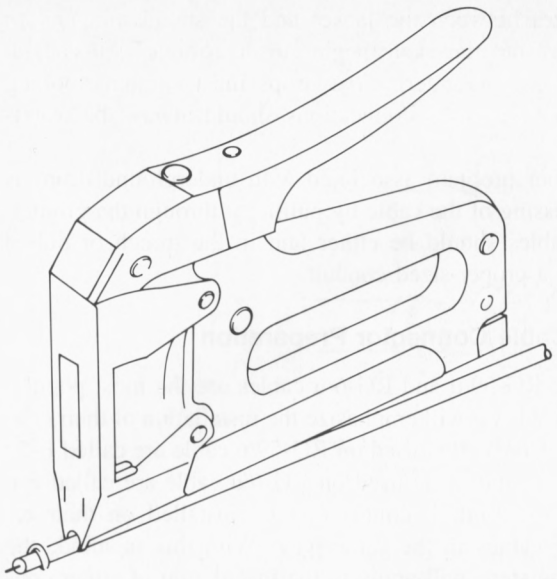


Fig. 15-23. Cable stapling gun (*Anixter Bros., Inc.*).

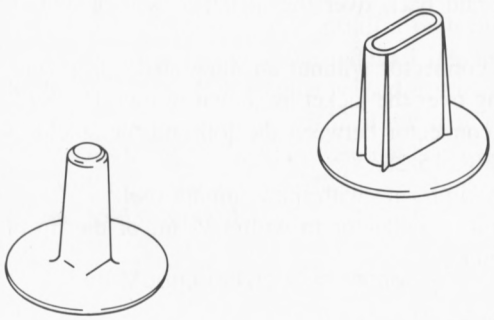


Fig. 15-24. Single- and dual-cable bushings (*Anixter Bros., Inc.*).

Fig. 15-25. Connector lock (*CWY Electronics*).

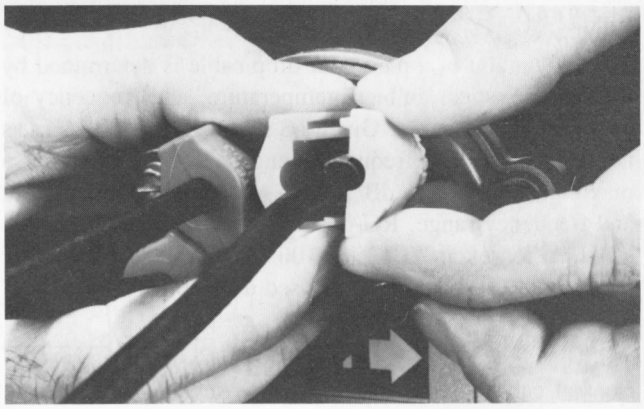


Fig. 15-26. Installing a cable lock (*CWY Electronics*).

DROP CABLE AND DROP-CABLE CONNECTOR PREPARATION

Types of Drop Cable

The types of coaxial cable used for subscriber drops are RG-59/u, RG 6/u, and RG-11/u. These cables all have a characteristic impedance of 75 Ω, and most are constructed with a (1) PVC jacket, (2) braided shield over aluminum tape, (3) copper-clad steel center conductor, and (4) foam polyethylene dielectric.

Coaxial cable used in subscriber drops may be either messengered (figure 8) or unmessengered, single or dual, and are available in either black-, white-, or beige-colored jackets. Dual cable is simply two separate cables joined together at the jacket. Dual cable is used on systems that carry more than 35 channels. The diameter of RG-59/u cable is approximately ¼ in., that of RG-6/u is approximately 5/16 in., and RG-11/u is approximately ½ in. in diameter.

Cable Selection

The choice of drop cable to use in an installation is dependent on the following factors.

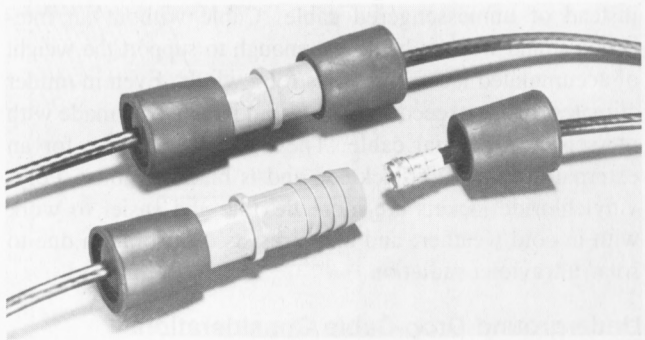


Fig. 15-27. Connector cover (*CWY Electronics*).

Attenuation

The attenuation of a particular drop cable is determined by its characteristics, ambient temperature, and frequency of operation of the cable. Given 68°F and 50 to 400 MHz as the temperature and frequency range, RG-59/u cable has a maximum loss of 5.6 dB/100 ft. At this same temperature and frequency range, RG-6/u losses are 4.8 db/100 ft, and RG-11/u losses are 3.12 dB/100 ft. Because of its larger diameter, RG-11/u is seldom used as drop cable.

Temperature

Coaxial cable losses vary with increases and decreases in temperature. As the temperature decreases, the attenuation decreases by 0.1 percent for every 1.0°F change. As the temperature increases, the attenuation will increase by 0.12 percent for every 1.0°F change. As an example, let us consider 75 ft of RG-59/u cable at 68 and 108°F. At 68°F the cable has 4.2 dB of loss. At 108°F (an increase of 40°F), the attenuation increases by 4.8 percent (40 × 0.12). This causes the attenuation to increase to 4.4016 dB of loss [4.2 + (4.2 × 0.048)]. From this it can be seen that 100 such drops could change the signal level by 20dB (100 × 0.2 difference).

Shielding

Cable shield selection is dictated by noise characteristics and expected service life of the coaxial cable. The longer the cable is expected to be in service, the better the shielding should be. The two types of noise associated with coaxial cable are ingress and egress. Ingressive noise is interference that enters the cable from external sources such as radio transmitters and electrical equipment. Ingress becomes critical as bandwidth increases or when two-way operation is desired. Egressive noise is caused by the radiation from the CATV system itself. Egress interferes with aircraft, navigational, and ground control equipment, as well as radio communications.

Aerial Drop-Cable Considerations

Factors to be considered when making an aerial drop are the climate and the length of the drop. If heavy icing and wind loading are factors, messengered cable should be used instead of unmessengered cable. Cable without an integrated strand will not be strong enough to support the weight of accumulated ice or tolerate strong winds. Even in milder climates, drops exceeding 75 ft should always be made with messengered coaxial cable. The best cable to use for an external drop is PVC-jacketed and is black in color. Polyvinylchloride jackets are more flexible and easier to work with in cold weather, and black resists deterioration due to solar ultraviolet radiation.

Underground Drop-Cable Considerations

The most frequently reported problem with underground drops is contamination due to moisture. Once moisture accumulates between the jacket and the shield, attenuation increases and the cable begins to deteriorate. All coaxial cable used for underground drops must contain flooding compound, and the connections should always be waterproofed.

Another problem associated with underground drops is overstressing of the cable by pulling it through the ground. Drop cables should be either laid in the trench or pulled through a proper-sized conduit.

Drop-Cable Connector Preparation

Because RG-59/u and RG-6/u cables are the most popular cables used, we will emphasize the installation of their connectors. Connectors used on RG-59/u cable are called F-59 connectors and those used on RG-6/u cable are called F-6 connectors. Both F connectors are installed on their respective cables in the same way. With this in mind, the following steps will apply to the installation of either connector:

1. Cut the cable to expose ½ in. of the center conductor as shown in Fig. 15-28*a*.
2. Strip off 3/16 in. of the jacket as shown in Fig. 15-28*b*.
3. Fold the braid back over the jacket as shown in Fig. 15-28*c*.
4. If using a connector without an integrated crimp ring, slip the ring over the jacket as shown in Fig. 15-28*d*.
5. Insert the connector between the foil and the shield as shown in Fig. 15-28*e*.
6. Crimp the crimp ring with the crimping tool.
7. Cut the center conductor to within ⅛ in. of the lip of the connector.

The Tap Connection

Aerial Tap Connection

There are two methods of bringing cable from the tap to the house: straight drops and midspan drops. Straight drops are fastened to span clamps located near the tap. Midspan drops are fastened to span clamps located a good distance from the tap. Midspan drops are required whenever property lines would be crossed with the use of a straight drop. Figure 15-29 shows both straight and midspan drops.

To make an aerial drop, the following steps are recommended:

1. Place an F connector on one end of a length of drop cable.
2. If the system uses heat-shrinkable tubing, slip a length over the drop cable and connector.
3. Climb the pole and fasten the connector to one of the tap ports.
4. Either apply a waterproofing compound to the connector or shrink the heat shrink tubing by applying heat from a torch flame.
5. Install a span clamp onto the strand if a straight drop is to be used.

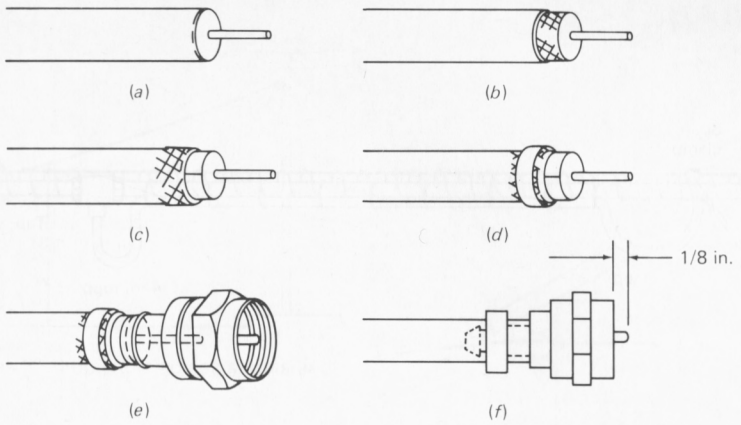


Fig. 15-28. Preparing cable for an F connector (*Times Fiber Communications.*).

6. If a midspan drop is to be used, form a 4-in.-diameter drip loop in the drop cable. Secure the cable to the feeder line with a tie as shown in Fig. 15-30. Continue tying the drop cable every 10 to 12 in. until the midspan location is reached. Install a span clamp. If a row house is to be connected, run the drops as shown in Fig. 15-31.
7. Allowing a 12-in. loop, install a preformed cable grip onto unmessengered cable and hook into the span clamp.
8. If messengered drop cable is used, form a dead-end drip loop as shown in Fig. 15-32 at the span clamp.
9. Make sure that aerial drops are not backfed, which would result in intrusion of the 30-in. sq. climbing space. Figure 15-33 shows the proper way to make an aerial drop.

Pedestal-Mounted Tap Connections

To connect a drop to a pedestal, the following steps are recommended:

1. Connect an F connector to one end of the drop cable.
2. Dig a hole next to the pedestal.
3. Feed the cable into the hole and bring it up into the open pedestal. Place a length of heat-shrinkable tubing over the connector if specified for that cable system.
4. Fasten the connector to one of the unused ports of the tap.
5. Either apply waterproofing compound to the connector or slip the heat-shrinkable tubing over the connector and heat.
6. Allow a 4-in. drip loop and fasten the drop to the feeder cable with a tie.
7. Fill in the hole and tamp down.

Making the House Connection

Aerial Cable Drops

Once the drop cable is secured to the span clamp, the installer must secure it to the house. The following steps are required to secure the drop to the house.

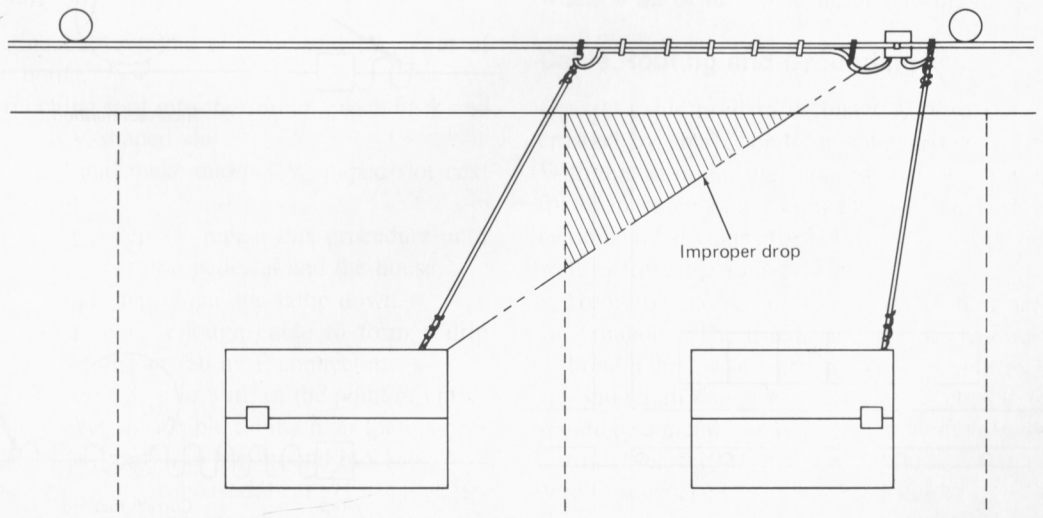


Fig. 15-29. Straight and mid-span drops.

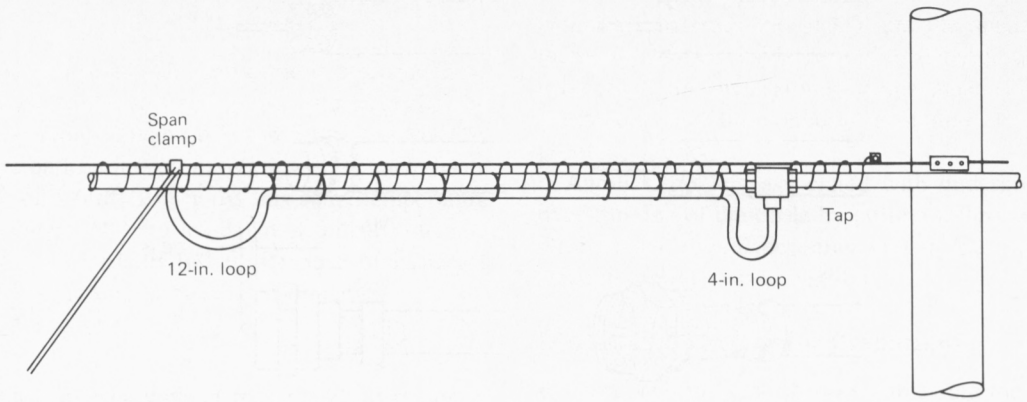


Fig. 15-30. Mid-span drop connection.

1. Determine the location where the drop cable is to be secured and install either a house hook or a drive ring.
2. Pull the cable to the hook or ring and install a preformed cable grip. Maintain the minimum distances as shown in Fig. 15-34.
3. On messengered cable, make a dead-end identical to that used at the span clamp (Fig. 15-32).
4. For unmessengered cable, form a 4-in. drip loop before fastening the cable to the house.
5. Run the cable to the area where it is to enter the home. Fasten it every 12 in. with one of the following: (*a*) bronze staples, (*b*) plastic cable clips with nails, (*c*) siding clips, or (*d*) drop cable clamps. The choice of fastener is dictated by the type of material the cable is to be fastened to. Siding clips, of course, are used on plastic or metal siding, while clamps are preferred for brick and masonry walls. Staples and plastic clips can be used only on wood.
6. Place a ground block within 8 in. of the point of entry. Place the ground block so that the F connectors will be oriented in a horizontal position. The position of the point of entry is determined by the location of the

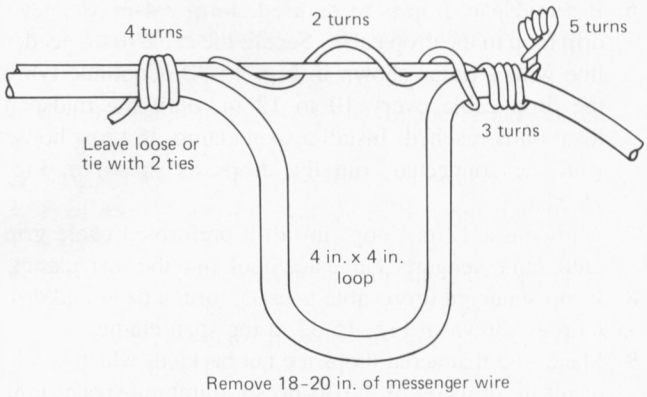
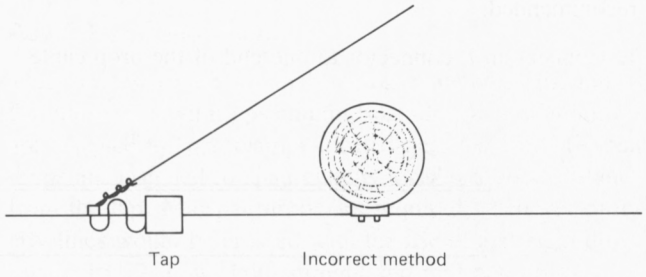


Fig. 15-32. Messengered cable dead-end.



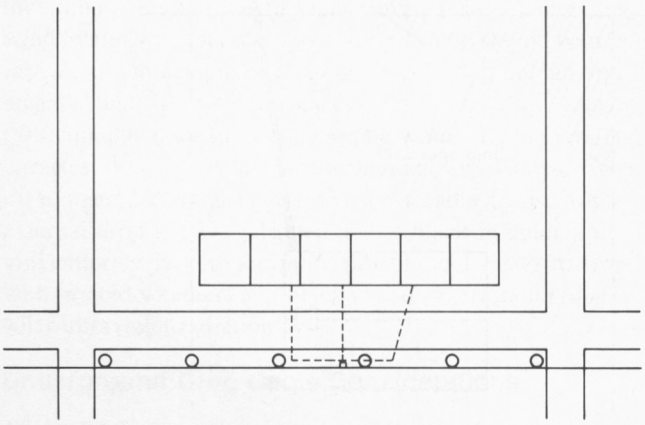


Fig. 15-31. Running drop cable to row houses.

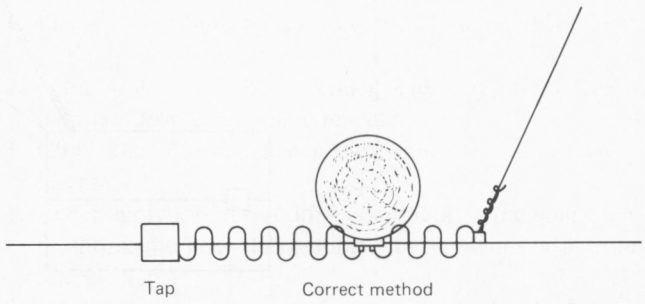


Fig. 15-33. Proper way to run drop to eliminate backfeeding.

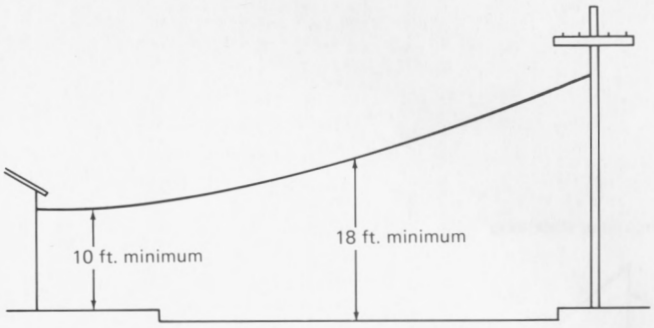


Fig. 15-34. Minimum clearances for drop cable across streets and yards.

TV set. For an upstairs room, the point of entry might be at a window. Generally the point of entry will be into the basement.

7. Bring the cable to within 8 in. of the ground block and form a 4-in. drip loop.
8. Cut the cable and install a connector.
9. Screw the connector on the side of the ground block opposite the point of entry.
10. Apply either waterproofing compound or heat-shrinkable tubing to protect the cable from moisture.

Figure 15-35 shows the relative position of the cable, drip loops, ground block, and bushing. For simplicity, we have shown the drop cable away from the window, but in an actual installation the drop cable should be placed as close to the window frame as possible.

When running cable from the house hook to the ground block, follow the natural contours of the home. What distinguishes a quality installation from a careless job is the way the installer ran the cable.

Buried-Cable Drops

Once the drop cable is secured to the feeder cable in the pedestal, the following steps should be adhered to:

1. Lay out a line between the pedestal and the point of entry to the home.
2. Force the trenching tool into the soil and rock back and forth to create a V-shaped slot.
3. Remove the tool and make another V-shaped slot next to the previous one.
4. Following the line (step 1), repeat this procedure until a trench exists between the pedestal and the house.
5. Force the cable into the trench and tamp down.
6. Making sure to provide enough cable to form a drip loop, cut the cable and install an F connector.
7. Install a ground block within 8 in. of the point of entry.
8. Slip a length of heat-shrinkable tubing over the connector, if required, and fasten to the ground block.
9. If heat-shrinkable tubing was used, heat to form a waterproof seal; if not, apply waterproofing compound to the connector to protect it from moisture.

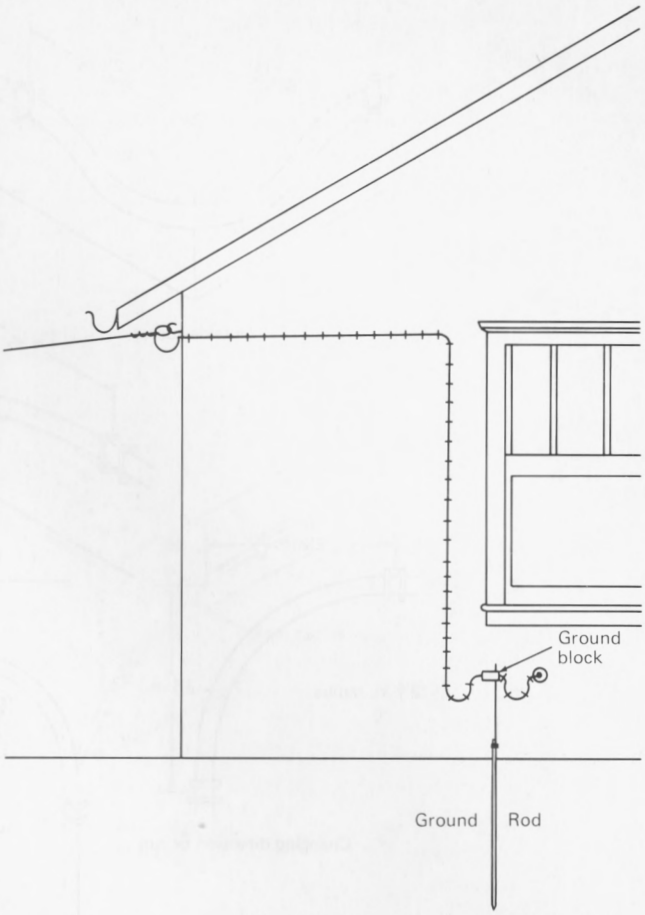


Fig. 15-35. Drop cable run from house hook to ground block.

The other side of the ground block is used to provide a connection for the cable going to the TV set. Usually, when a splitter is used to provide signals to more than one set, it is located in the basement. In those cases where a splitter must be located outside the home, a weatherproofed combination ground block and splitter is used and mounted within 8 in. of the point of entry to the home.

Cable Routing and Grounding

Coaxial cable used to deliver CATV signals must not be crushed by sharp bends or subjected to excessive stress. With this in mind, the cable industry has set up guidelines for drop cable radii. Figures 15-36 and 15-37 show the recommended values for both inside and outside corners as well as for cable runs.

To protect the subscriber's home, subscriber drop cables are grounded. The usual method of grounding drop cables is through the use of a ground block. Various ground blocks are shown in Fig. 15-38. The first choice for a ground should be a metal (not plastic) cold-water pipe that is known to run at least 10 ft through the earth. To secure a ground wire to a water pipe, a ground clamp (Fig. 15-10) is used. To ground the ground block, run a length of bare copper wire from the ground block to the clamp. The solid copper

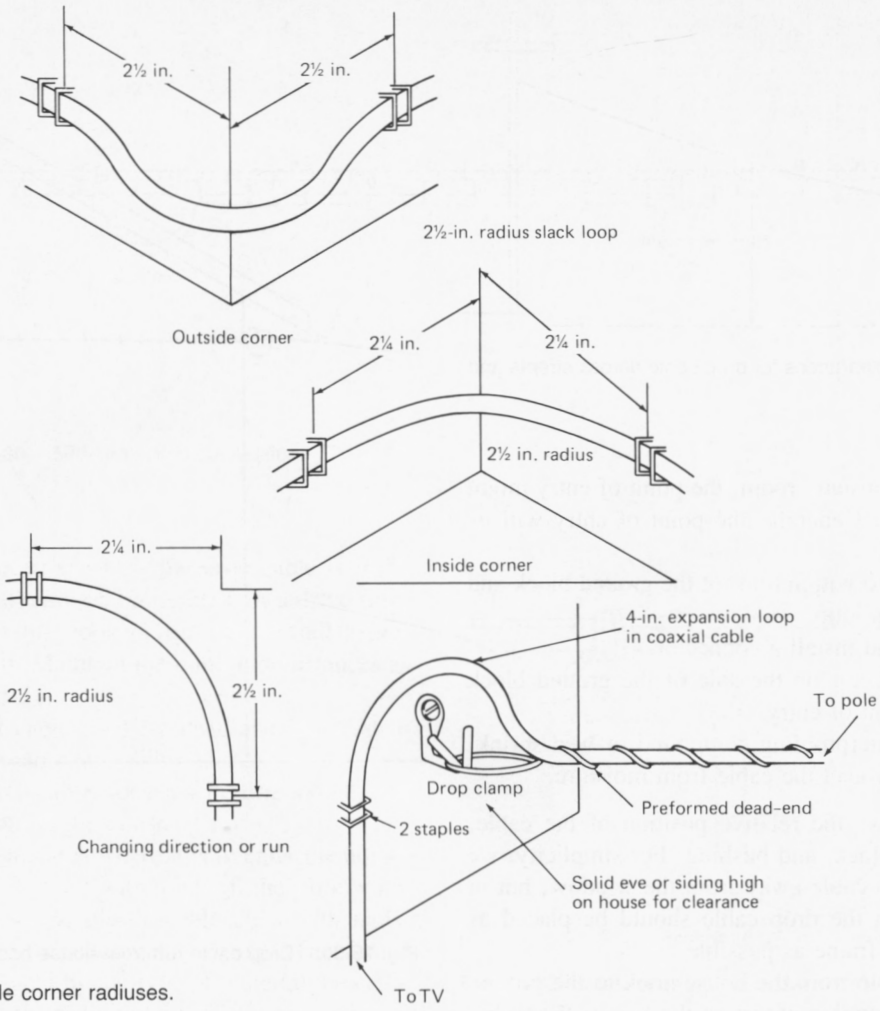


Fig. 15-36. Drop-cable corner radiuses.

wire (AWG No. 12 or larger) is then fastened to the ground block through the ground blocks set screw. The other end is fastened to the ground clamp set screw. Before installing the clamp, make sure that the pipe is free of paint or corrosion. The length of the ground wire should not exceed 20 ft.

In cases where the distance to a water pipe or power company neutral is greater than 20 ft, a ground rod is used. The ground rod should be hammered into the ground as close as possible to the ground blocks location. Leaving about 6 in. above the ground, attach a ground rod clamp and secure the ground wire coming from the ground block. Figure 15-39 shows the grounding of a ground block by use of a ground rod and clamp. If the ground rod stub presents a hazard, hammer the rod, with clamp and ground wire attached, into the ground.

SUMMARY

1. The installer's responsibility is to run cable from the tap to the subscriber's TV set.
2. Some of the tools used by installers include (*a*) trenching tool, (*b*) drop-cable preparation tool, (*c*) connector tool (crimper), (*d*) cable caddie, and (*e*) stapler.
3. Some of the devices used by installers include (*a*) cable connectors, (*b*) ground rods and clamps, (*c*) grounding straps and clamps, (*d*) ground blocks, (*e*) splitters, (*f*) coaxial cable switches, (*g*) apartment boxes, (*h*) house hooks and drive rings, (*i*) span clamps, (*j*) drop-cable grips (dead-ends), (*k*) fasteners (e.g., clips, staples, metal clamps), (*l*) feed-through bushings, (*m*) connector locks and covers, and (*n*) wall plates.
4. The three most common types of drop cables are RG-6/u, RG-59/u, and RG-11/u.
5. Selection of the proper cable to use is dependent on attenuation, temperature variations, and shielding.
6. Ingress is interference *entering* the cable from outside sources.
7. Egress is interference caused by signal *leaving* the cable.
8. The two routes for bringing a subscriber drop cable into the home are aerial and underground.
9. *All* coaxial cable must be grounded to provide protection from stray electrical charges.
10. The usual method of providing a ground is through the use of a ground block and ground wire. The ground wire is connected to either a ground rod, cold-water pipe, or the power company neutral connection.

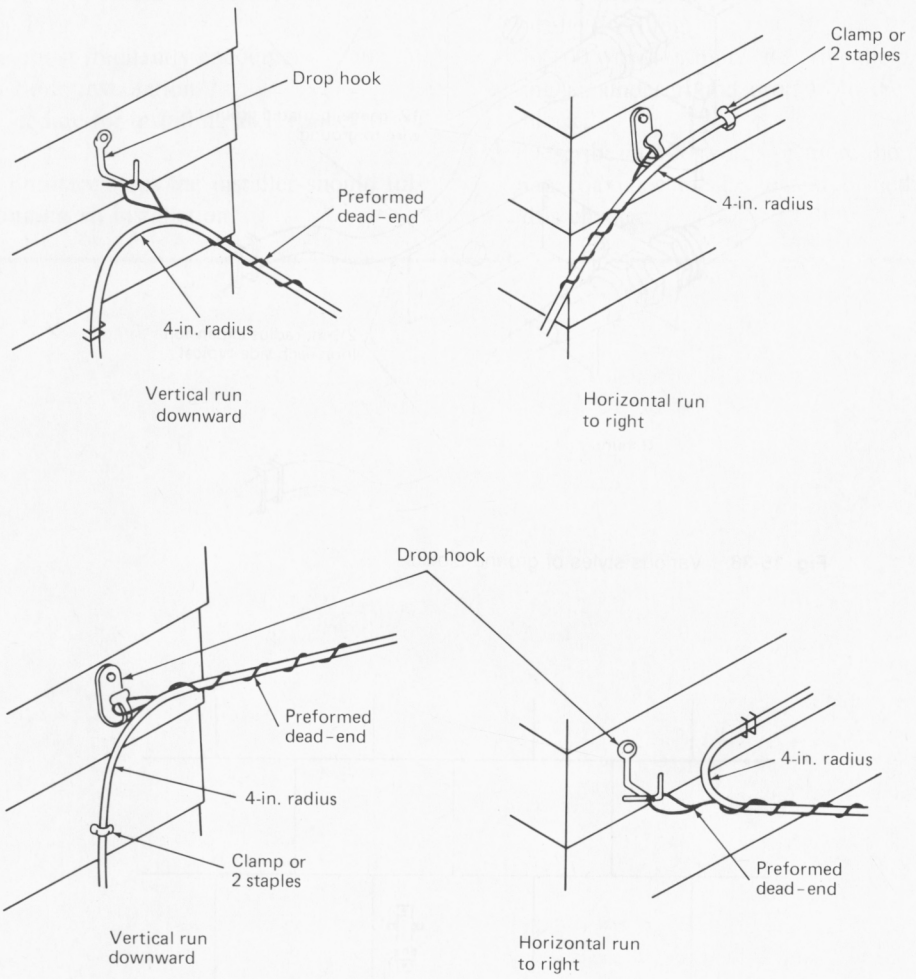


Fig. 15-37. Proper radii at house hooks.

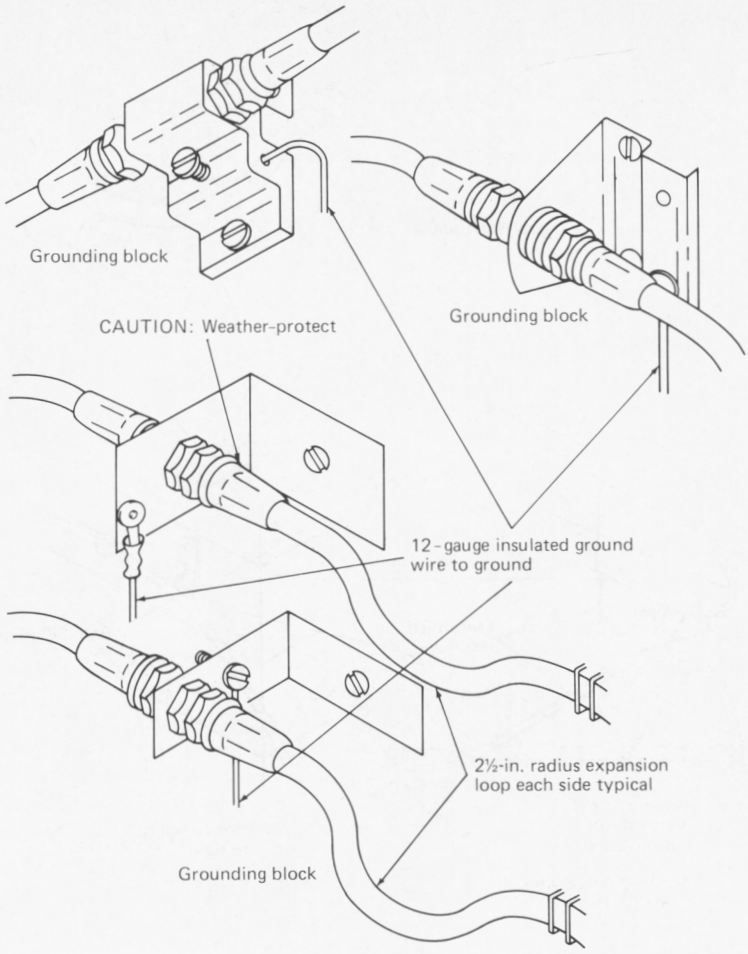


Fig. 15-38. Various styles of ground blocks.

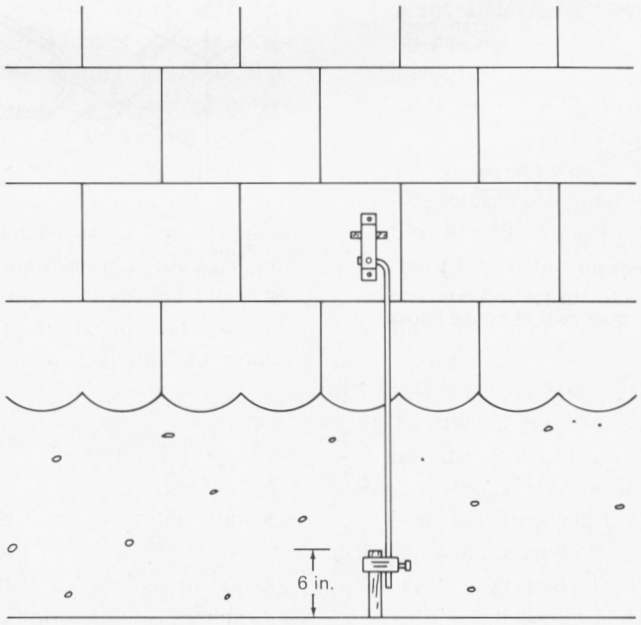


Fig. 15-39. Proper method of running a ground wire from ground block to ground rod.

REVIEW QUESTIONS

1. What part of the cable distribution system is considered the most important link in the signal chain?
2. Name five tools used by installers.
3. Name 10 devices used by installers.
4. How is a trenching tool used?
5. Describe the coaxial cable used for subscriber drops.
6. What is the difference in attenuation when RG-59/u cable is used in an area that experiences a temperature variation of -10 to 110° F?
7. What is ingress?
8. What is egress?
9. What factors should be taken into consideration when making an aerial drop?
10. What problem is most frequently encountered with underground drop-cable installations?
11. Describe the procedure for installing an F connector on a drop cable.
12. Name three preliminary steps the installer should follow before beginning an installation.
13. Name five pieces of information contained in the company literature generally given to new subscribers by the installer.
14. What is the difference between a straight drop and a midspan drop?
15. In 100 words or more, describe the procedure for making an aerial drop, tap connection.
16. What results when aerial drops are backfed?
17. When making an aerial drop to the house, what is the minimum distance that the cable must clear over the center of the street?
18. Name three methods of fastening drop cable to the side of the dwelling.
19. In 100 words or more, describe the procedure for bringing an underground drop from the tap to the ground block.
20. Describe in 100 words or more the process of grounding coaxial cable by the three methods mentioned in this chapter.

16
CHAPTER
WIRING THE SUBSCRIBER'S HOME FOR CATV SERVICE

INTRODUCTION

In this chapter you will learn about:

1. The test equipment used in CATV
2. Installation of single cable service
3. Installation of dual cable service
4. Multidwelling installations
5. Connection of FM service
6. Connection to video cassette recorders
7. Fire, burglar, and medical alarm service
8. Installation problem-solving techniques

Wiring of a subscriber's home for CATV may be done either before or after construction is complete. If the home is wired before the construction is finished, it is called *prewiring* the home. If the home is wired after the construction is complete, we say that the home was *postwired*. Because most installations are postwired, we will concentrate on that method of wiring.

TEST EQUIPMENT USED IN CATV

The test equipment used to maintain a modern cable system is utilized for measurements of (1) voltage, current, and resistance; (2) signal quality, level, and radiation; (3) cable location; and (4) explosive and poisonous gas levels. The following instruments are representative of these categories of test equipment.

Volt-Ohm-Milliammeter

The volt-ohm-milliammeter (VOM) is a multipurpose, self-contained unit that is used to measure electrical potential (volts), current flow (amperes), and resistance to current flow (ohms). The VOM is designed to measure ac and dc voltage, dc amperage, and resistance. A VOM may be carried in the worker's toolbox or in a pocket. The two main uses of the VOM for cable-related tests are to measure the voltage at wall receptacles and to find cable resistance. Unlike the meter shown in Fig. 16-1, which uses only one switch, most VOMs contain a meter, a function switch, and a range switch.

To measure the 120 V at a wall receptacle, the meter should be set up as follows:

Fig. 16-1. Volt-ohm milliammeter (*CWY Electronics*).

1. Set the function switch to the AC position.
2. Set the range switch to a *voltage* value greater than 120.
3. Place the two leads (red and black) into the receptacle slots.
4. Read the value of the voltage on the meter.

To measure resistance, the VOM is set up as follows:

1. Place the function switch in the + DC position.
2. Place the range switch in the ohms range that will measure the expected resistance. For example, a short piece of wire would only be expected to have a small resistance; therefore, place the switch in the R × 1 position.

WARNING Ohmmeters are never to be used on circuits that are energized.

To test a piece of cable, first disconnect each end and place the leads on the center and outside conductors. A movement of the meter indicates that both conductors are touching (short circuited) somewhere in that length of ca-

ble. A good piece of cable will not show a meter indication. Tests such as the one described above are always done on the R × 1 scale and are known as *continuity tests*.

The two most probable causes of a short circuit are staples touching inner and outer conductors or a bad connector connection.

The proper use, maintenance, and testing procedures for individual VOMs are contained in the instruction manual for each product.

TV Test Set

The TV test set is usually a small-screen black-and-white set used to determine the condition of cable signals. Although it takes longer to make an installation if the test set is used, it is worth the extra time. Knowing that a problem exists before the subscriber is aware of it, the installer has time to remedy it. One of the most serious errors that an installer can make is to allow the subscriber to see poor reception. The TV test set also allows the installer to show the subscriber that a reception problem is in the subscriber's TV set and not on the cable. Side-by-side comparison can be made by hooking both the subscriber's set and the test set to the cable.

It goes without saying that the TV test set should be of very good quality. It should exhibit sharp, clear, and distortion-free pictures and sound and have an AGC control. Just like any piece of test equipment, it should be handled with care and maintained in good operating condition.

Signal-Level Meter

The most important piece of test equipment used by cable workers is the signal-level meter (SLM). The SLM is basically a tuned voltmeter whose scales are calibrated in either dBmV units or microvolts. A portable SLM is shown in Fig. 16-2.

The choice of an SLM is probably one of the most important decisions a CATV company must make. Signal-level meters are available in all sizes, shapes, and price ranges. Because of the job it performs, the SLM should be judged on quality rather than price. Signal-level meters used by installers and service technicians are generally battery-powered and built more ruggedly than are bench models. Most systems require installers and service personnel to record SLM readings on the work order. This practice is important because it allows the engineering staff to evaluate the system under varying conditions.

The SLM shown in Fig. 16-2 is divided into seven basic sections:

1. *Frequency selectors*—used by the cable worker to make signal level measurements on different cable frequencies.
2. *Meter*—used to measure the level of signal on the cable and indicate the condition of the internal battery.
3. *Speaker*—used by the worker to hear an interfering signal. The speaker also allows the sound portion of the channel to be monitored, if needed, for troubleshooting.
4. *Audio switch*—used to turn the audio portion of the signal either on or off according to the needs of the worker.
5. *Battery test switch*—allows the meter to be used to show the condition of the built-in battery.
6. *Power switch*—used to either apply power to or remove power from the SLM.
7. *Attenuation pads*—used to attenuate (reduce) the level of the signal to avoid overloading of the meter.

Fig. 16-2. Signal-level meter (*Sadelco, Inc.*)

For use of the SLM, the following steps are recommended:

1. Place all the attenuators to the ON position. This will result in 70 dB of attenuation to the incoming signal. Some SLMs have only one 20-dB pad and two 10-dB pads, allowing attenuation values from only 0 (all switched out) to 40 dB if all are switched in.
2. Connect the cable to the coaxial connector on the SLM.
3. Adjust the frequency selector for the video signal of Channel 2 (55.25 MHz) and rock back and forth until a maximum reading is achieved. If the meter barely moves, switch out the 10-dB attenuator and rock the selector knob until the needle peaks. If the meter still does not give an adequate reading, switch the 10-dB attenuator back in and switch out a 20-dB attenuator. Continue switching attenuators to find an acceptable reading.
4. Once a good reading is obtained, record the value on the work order. A good reading is one that causes the needle to go past the midpoint on the scale.
5. Adjust the frequency selector to the video signal of Channel 13 (211.25 MHz) and repeat steps 3 and 4, using the new frequency value.
6. Repeat steps 3 and 4 for any other channels requested by the cable system.
7. When finished, place all the attenuators in the ON position and disconnect the cable.
8. Check the battery condition and recharge, if necessary.

Signal-level meters are delicate and should be placed in a padded holder when transported; they should also be calibrated on a regular basis and protected from water. If it becomes necessary to measure the cables' signal during a rainstorm, cover the SLM with clear plastic.

Besides measuring the signal levels on the system, SLM can be used for the following purposes:

1. *Measuring insertion loss*. Compare the input to the output level of the device to determine insertion loss.
2. *Determining the frequency of an interfering signal*. By adjusting the frequency selector and listening for the interfering signal, its approximate frequency can be found.
3. *Balancing head-end channels*. By measuring the output levels of each channel leaving the head-end and inserting attenuator pads in those channels whose levels are high, the cable channels can be balanced.
4. *Measuring the gain of amplifiers*. By subtracting the input level from the output level, the relative gain of an amplifier can be found.
5. *Determining the slope of the system*. Slope is the difference between the signal level at the lowest frequency compared to the level at the highest. By making measurements at both extremes, the difference is the slope or tilt.

Radiation Detector

This piece of test equipment uses a special transmitter at the head-end to send a tone down the cable. Using an FM radio, or specialized detector the technician patrols the lines listening for a beeping sound. The closer the worker gets to the source of egress, the louder the sound becomes.

Buried-Cable Locator

A buried-cable locator is an instrument that not only locates buried cable but also detects damaged cable. This piece of test equipment can save many hours of digging up buried cable looking for the faulty section.

A cable locator consists of a transmitter unit, a receiving unit, and a frame that contacts the earth.

To locate a buried cable, connect the transmitter to the cable shield. A tone is then sent along the cable and followed by the hand-held receiver. When directly over the cable, either a maximum meter reading is obtained or the tone in the headphones becomes louder.

To find a faulty section of cable, the transmitter is connected to the shield and a tone is sent along the cable. After all the grounds (bonds) are removed from that section of cable, the frame is aligned with the cable run and moved toward the suspect portion. As the frame gets closer to the defect, a meter indicates its location. Cable locators can detect a fault in open country as well as under driveways, streets, and parking lots.

Gas Indicators

Whenever personnel must work in manholes, some form of indicating device is needed to test for gases—not only oxygen, but poisonous and explosive gases as well.

A gas indicator consists of a probe, a connecting hose, a sensing chamber, and an aspirator bulb. The sensing chamber is different for each classification of gases.

To sense the presence of poisonous or explosive gases, use the following procedure:

1. Squeeze the aspirator bulb to allow fresh air to replace any gases in the probe, connecting hose, or sensing chamber.
2. Insert the probe into the vent holes of the manhole cover. Never remove a manhole cover until you are certain that explosive gases are *not* present. Any scraping can cause a spark that might ignite the gas.
3. Squeeze the aspirator bulb three times to allow sufficient air to enter the sensing chamber.
4. Check the meter to determine the condition of sample.
5. If the sample does not indicate the presence of poisonous or explosive gas, repeat this test at various levels.
6. If no poisonous or explosive gases are found, ventilate with a manhole ventilator.

SINGLE CABLE INSTALLATIONS

Previously we brought the cable from either the tap or the pedestal to the house, secured it, and ran it to the ground block. We will now bring it into the home and distribute its signals. As we go through a typical single cable installation, we will cover as many variables as possible.

Choice of Method

The methods used to bring the cable into the home are dependent on many factors, such as those described below.

Customer Preference

Although we may have a clear-cut method outlined for the installation, the subscriber may disagree. Some subscribers would not object to having a hole drilled through an outside wall, provided it is done properly, whereas others may. In some cases subscribers may wish to have the cable run through walls rather than being brought up through a hole drilled in the floor. Although the customer's wishes should be taken into consideration, the ultimate decision rests with the installer. As a general rule, the cable company charges a minimum amount for a simple installation and anything unusual costs the subscriber extra. Most subscribers who are looking for custom installations are reluctant to pay extra; therefore, they will generally modify their requests. On those occasions when the subscriber insists on something extraordinary, suggest that the work be done by an outside CATV contractor.

Type of Home Construction

There are basically three types of dwellings encountered by installers: (1) homes with basements; (2) homes built on concrete slabs; and (3) homes built above grade, having a crawlspace.

Type of Siding

The various types of siding that an installer comes in contact with are wood, asbestos shingles, brick, and plastic or metal siding. Each type of siding must be handled in a different way in order to provide an access route for the cable.

Location of the Set(s)

The location of the TV set(s) often dictates how the cable is to be run within the building. The TV set location may also determine the point of entry needed to make a good installation.

Making the Installation

Once the point of entry is decided on, the installer drills a hole and inserts a bushing. The size of the hole depends on the type of cable to be used. Single cable requires a 7/16-in. hole for its bushing, while a ¾-in. hole is made for dual cable bushings. *All* holes drilled through an exterior wall are to be drilled from the inside and should be angled downward at approximately 10°. Figure 16-3 shows the proper way to drill an entry hole through the floor joist. The reason for angling the hole at a 10° angle is to prevent rain water from entering the building. The reason for drilling from the inside is to prevent drilling through hidden objects such as ducts, pipes, and wiring. The best tool for drilling holes through anything except masonry is the bell-hanger bit. To drill through a brick facing, drill through the floor joist with a bell-hanger bit, then continue with the masonry bit. Whenever a bushing is placed in an entry hole, apply sufficient waterproofing compound to form a good seal. Besides drilling a hole through an exterior wall, entry may be made through window frames and attics.

Homes With Crawlspace Or Basement

For a home with a crawlspace or basement, the following steps are used to bring the cable to the TV set(s):

1. Measure the distance between the point of entry and the location of the TV set or splitter.
2. Cut the cable long enough to reach, plus an additional 10 ft for radii, a drip loop, and extra at the set.
3. Feed the cable out of the bushing, install a fitting, connect it to the ground block, and form the drip loop.
4. Fasten the cable to the side of the home and pull the excess back into the basement or crawlspace.
5. If the entry was through the floor joist, form a 2½-in. radius and secure with two staples.
6. Make the cable run as direct as possible and secure with staples every 16 to 18 in.
7. If the cable is to continue to the TV set, form a 2½-in. radius and bring up through the floor.
8. If the cable is to go to a splitter, cut to length and install an F connector, then mount the splitter in a location that will not interfere with any future remodeling by the subscriber.

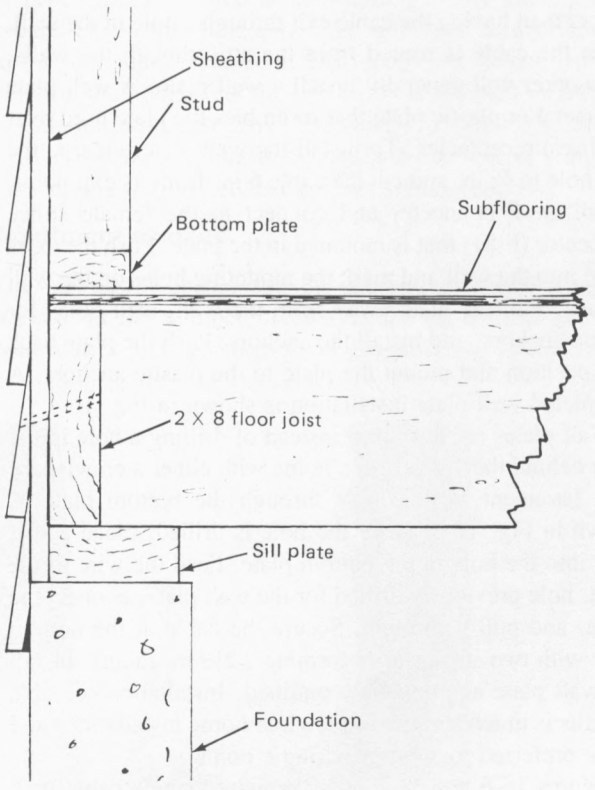


Fig. 16-3. Drilling of an entry hole.

9. Determine the length of the radials from the splitter to the TV sets, cut the wire, and install F connectors.
10. Run the radials to their respective locations, form a radius, and bring up through floor. If a three-way splitter is used, put the longest radial on the low-loss leg.

Homes Built on a Slab

For a home built on a slab, the following steps are used to bring the cable to the TV set(s):

1. Measure the distance between the point of entry and the location of the TV set or splitter.
2. Cut the cable long enough to reach, plus an additional 10 ft for radii, a drip loop, and extra at the set.
3. Feed the cable out through the bushing, install a fitting, connect to the ground block, and form the drip loop.
4. Fasten the cable to the side of the house and pull the excess back through the entry point.
5. Form a 2½-in. radius and run along the baseboard to the TV set. Remember to observe the proper radii and staple every 6 to 8 in.
6. If the cable is to go to a splitter, cut to length and install an F connector. Mount the splitter in an area that is not easily seen.
7. If a splitter was used, determine the length of the radials, cut the wire, and install an F connector.
8. Run the radials to their respective locations, leaving 4 to 6 ft extra. If a three-way splitter is used, put the longest radial on the low-loss leg.

Using Wall Plates

Rather than having the cable exit through a hole in the wall, when the cable is routed from the attic though the walls, the worker will generally install a wall plate. A wall plate is a metal or plastic plate that resembles the plate used over electrical receptacles. To install the wall plate, enlarge the exit hole to ¾ in. and cut the cable 6 in. from its exit point. Install an F connector and connect to the female splice connector (F-81) that is mounted in the plate. Push the extra cable into the wall and mark the mounting holes on the wall surface. Pull the plate away from the wall, drill holes for plastic anchors, and install the anchors. Push the plate back into position and mount the plate to the plastic anchors. A completed wall plate installation is shown in Fig. 16-4.

Wall plates are also used instead of drilling a hole in the floor behind the TV set. In a home with either a crawlspace or a basement, drill a hole through the bottom plate as shown in Fig. 16-5. After the hole is drilled, place a stiff wire into the hole in the bottom plate. Feed the wire to the ¾-in. hole previously drilled for the wall plate, connect the cable, and pull it through. Secure the cable at the bottom plate with two staples after forming a 2½-in. radius. Install the wall plate as previously outlined. Installation of cable in walls is much simpler in prewired home installations and is the preferred method of wiring a home.

Figures 16-6 and 16-7 show prewired single cable wall plates installed in wall boxes.

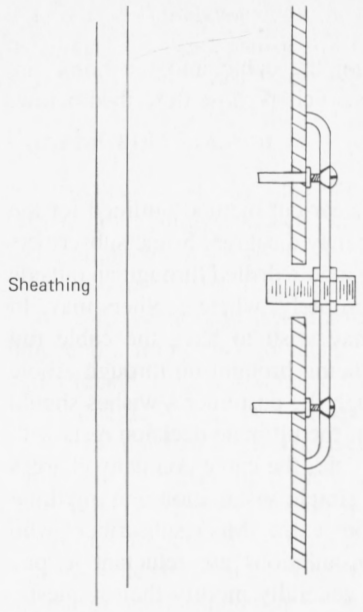


Fig. 16-4. Wall plate installation.

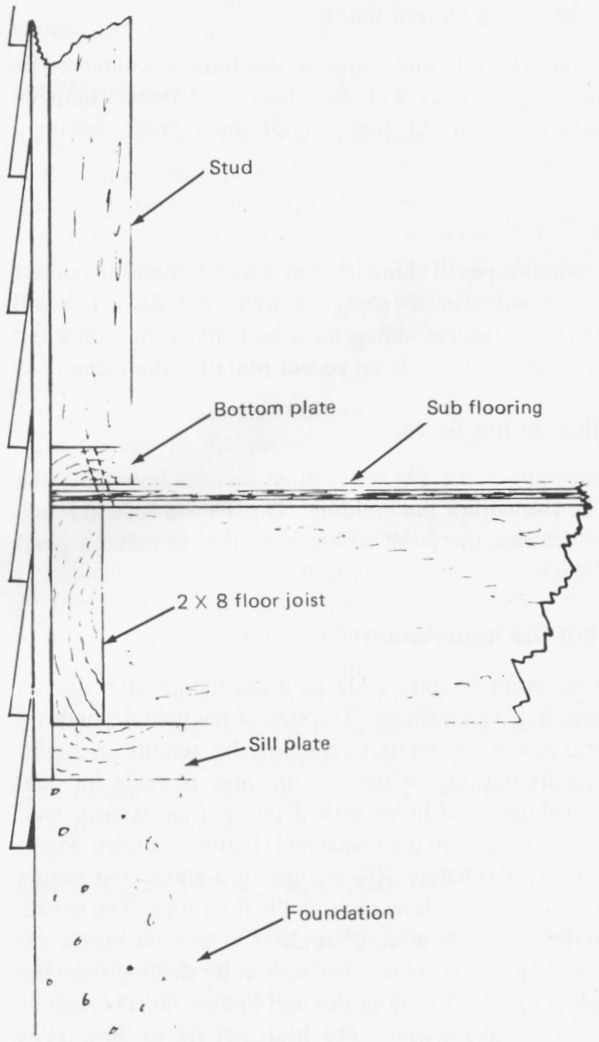


Fig. 16-5. Drilling a hole to admit cable to a wall plate.

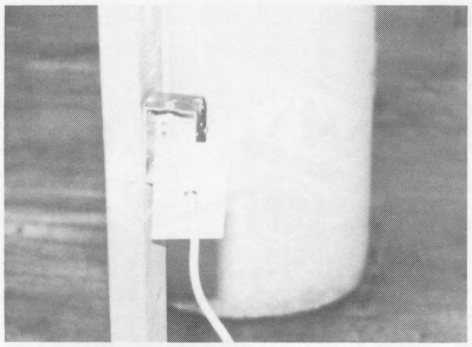


Fig. 16-6. Single wall plate showing route of cable to the outlet box.

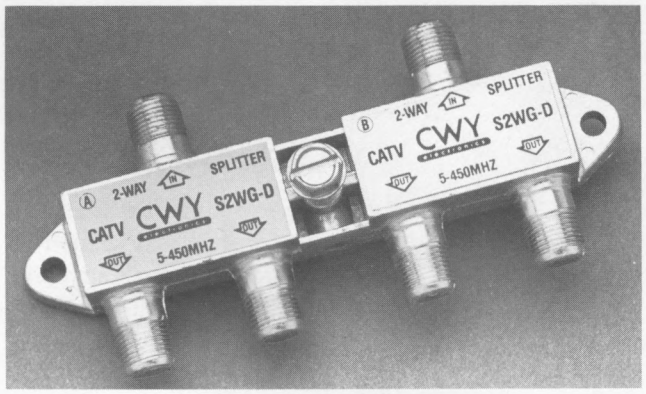


Fig. 16-8. Dual two-way splitter (*CWY Electronics*).

To better serve the color scheme of the subscriber's home, cables are available with beige and white jackets. Jackets of these colors are easier to camouflage, especially when run along baseboards and over doorways.

DUAL CABLE INSTALLATIONS

The installation of dual cable is basically the same as with single cable except that dual splitters and wall plates are used. Figure 16-8 shows a dual two-way splitter. Two F-81 female splice connectors are mounted on wall plates used on dual cable systems. Figures 16-9 and 16-10 show prewired dual cable wall plates installed in wall boxes.

MULTI-DWELLING INSTALLATIONS

Installing cable in high-rise, duplex, triplex, and apartment houses is different from that in single-family dwellings. The routing of these buildings is covered in this section.

High-Rise Buildings

The entry of coaxial cable into a high-rise building is through the basement. A high-rise edifice is handled in the same manner as an entire street of single-family homes. A 0.412 or 0.500 cable is brought to a central location of the building and taps installed at each floor. A secure location for the feeder cable is in the elevator shaft. Because of this location, security devices are not needed to protect the cable from theft.

When an apartment requests service, the installer simply runs a cable from the nearest tap to the subscriber. The cable run may be placed in ductwork or placed in conduit secured to the ceiling in the hallway. Running of the cable within the apartment is done similarly to that in homes built on slabs. Connector locks such as the one shown in Fig. 15-25 are generally all that are needed in areas with poor security.

Duplex and Triplex

All family dwellings connected together are wired the same as a single-family home, except that the splitters are installed outside. A drop is brought from the tap at the pole or pedestal and secured at the building. After passing the ground block, the cable enters the splitter to be distributed to the individual residences. Drip loops are formed before entering the homes and the cable run as outlined in earlier installation procedure lists. The reason for outside splitters is to enable the installer to discontinue one service without interrupting the service to the other subscribers.

Apartment Houses

The size of the cable and the amount of signal needed depend on the number of apartments. Apartment houses with four or less apartments can generally be handled with

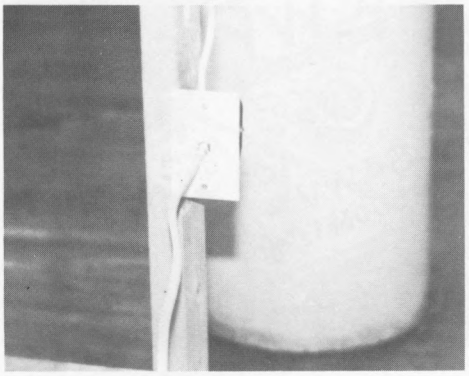


Fig. 16-7. Single wall plate installed.

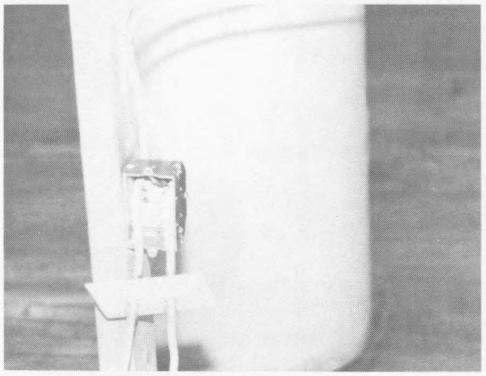


Fig. 16-9. Dual wall plate showing route of cable to the outlet box.

Fig. 16-10. Dual wall plate installed.

RG-6/u drop cable and a four-way splitter. Any apartment house with over four apartments can be served with 0.412 coaxial cable feeding an apartment box (Fig. 15-16). For the sake of definition, we will define an apartment house as a building not exceeding three floors. The individual drops are routed from an apartment box located in the basement of the building to each subscriber's apartment. The method of routing is dependent on the interior makeup of the building. Some of the more acceptable routes are through (1) cold-air ducts, (2) elevator shafts, and (3) conduit run parallel with power and telephone service conduit.

In extreme cases, drop cable may be run on the outside of the building and brought in through window frames. When this method is used, special plastic risers are used that blend in with the natural contours of the building.

Because an apartment box is used, security devices such as connector locks are not required. Figures 16-11 to 16-15 are examples of splitters used within an apartment box.

CONNECTION TO THE TV SET

In areas where 12 or fewer channels of cable service are offered, the cable is brought straight to the set. At the set

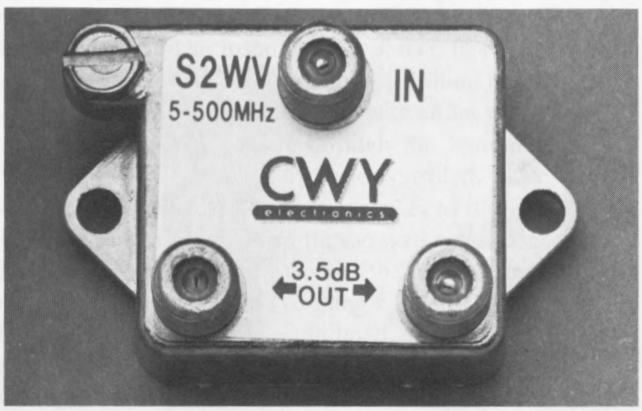


Fig. 16-11. Apartment-box-style two-way splitter (*CWY Electronics*).

Fig. 16-12. Apartment-box-style three-way splitter (*CWY Electronics*).

side of the cable, an F connector is installed and a matching transformer connected. The matching transformer is used to match the 75-Ω cable to the 300-Ω input of the set. The leads from the matching transformer are attached to the screw terminals on the back of the set labeled VHF.

To receive the cable programs, the subscriber simply turns the VHF dial to the desired channel. On sets equipped with a 75-Ω connector, omit the matching transformer and hook the cable up directly to this connector.

On cable systems that offer over 12 channels, a converter is used. A converter is an active device that changes (converts) the cable channels to a low VHF frequency. On such systems, the cable is connected to the input connector on the converter. A short section of cable is then used to connect the output of the converter to a matching transformer. The VHF channel selector on the TV set is then left on either Channel 2, 3, or 4, depending on the cable system. When selecting a channel to watch, the subscriber simply

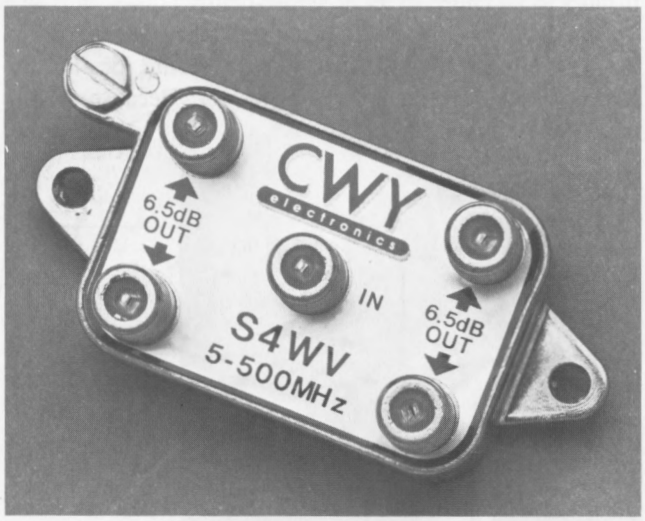


Fig. 16-13. Apartment-box-style four-way splitter (*CWY Electronics*).

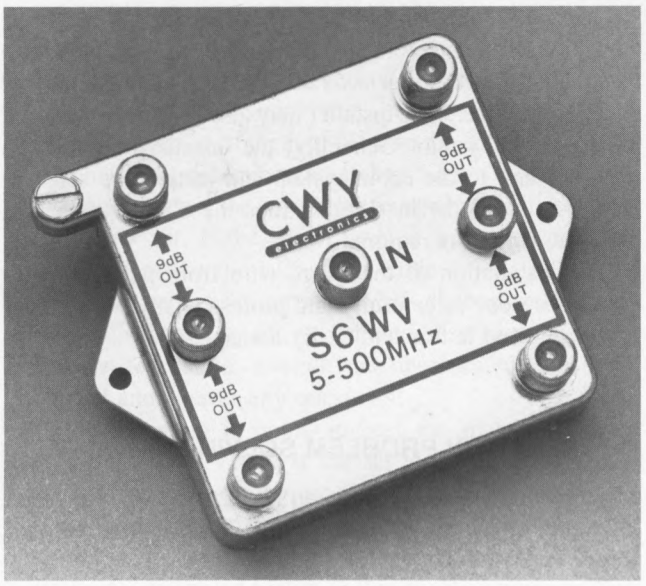


Fig. 16-14. Apartment-box-style six-way splitter (*CWY Electronics*).

uses the converter hand control unit. On systems that operate between 50 and 300 MHz and have more than 35 channels of programming, dual cable is utilized. What the cable system does in effect is to place half of their programming on one cable and half on another. To select which cable will supply a signal to the converter, an *AB* switch may be used. To watch the programs on one cable, the subscriber simply puts the switch in the *A* position and to watch the programs on the other cable, in the *B* position. The procedures explained above are typical of an older system. In a more modern system, the hand control unit tells the converter which cable to accept signals from. These converters display not only the channel, but also which cable it is using.

CONNECTION TO FM SERVICE

For those subscribing to it, a cable system will provide an FM signal that gives a simulated stereo sound to the TV program. To receive this signal, a special splitter designed to provide isolation is used. This splitter separates the FM signal from the TV signal. Figure 16-16 shows such a splitter. To receive this signal, the installer connects a length of cable from the FM output of the splitter to a matching transformer. The leads of the transformer are then connected to the antenna terminals of an FM radio receiver. The FM radio is then tuned to the cable signal.

CONNECTION TO VIDEO CASSETTE RECORDERS

To enable cable subscribers to record programs on a video cassette recorder (VCR), two methods of hookup are possible.

One-Converter Setup

This hookup allows the subscriber to tape the same program that is being watched. In this method, both the VCR and the TV set are tuned to the same channel. Figure 16-17 shows the wiring diagram for a one-converter VCR hookup.

Two-Converter Setup

This hookup utilizes two converters and enables the subscriber to tape one channel while watching either it or another channel.

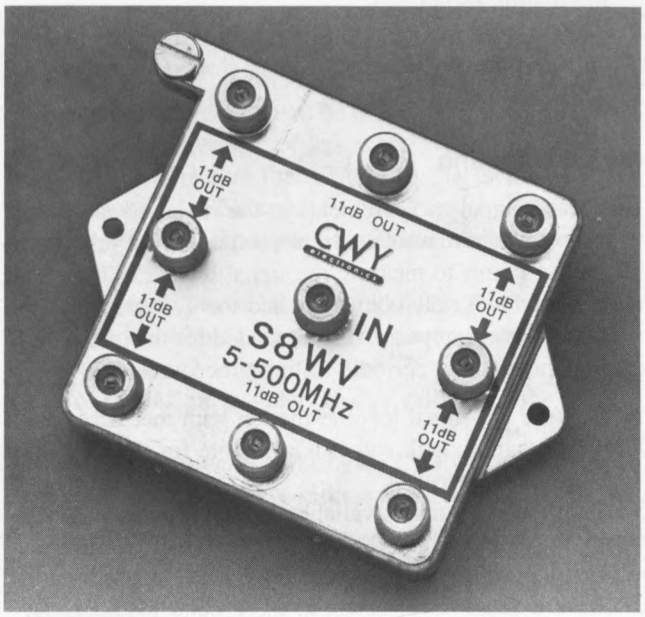


Fig. 16-15. Apartment-box-style eight-way splitter (*CWY Electronics*).

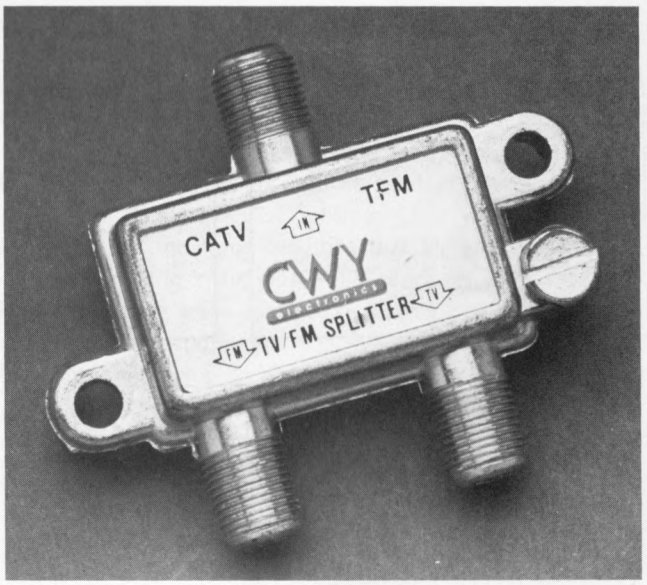


Fig. 16-16. FM splitter (*CWY Electronics*).

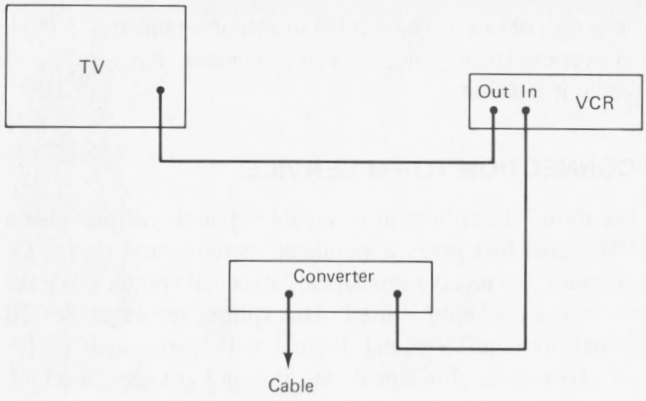


Fig. 16-17. Single-converter VCR hookup.

Looking at Fig. 16-18, we can see that an *AB* switch is used. The *AB* switch is used to connect the TV set to either the output of the VCR or converter 1. In the *A* position, the subscriber can view any channel on the system while taping a program on another channel. In the *B* position, the subscriber can view only the program being taped or played back.

CONNECTION OF FIRE, BURGLAR, AND MEDICAL EMERGENCY ALARMS

In addition to the regular programs offered to subscribers, some cable systems offer fire, burglar, and medical alarm services.

Basically the system polls, several times per minute, the homes of subscribers who contract for these services. If a medical alert button or a sensor used for fire or burglary detection is tripped, the authorities are notified. All the sensors are connected to a terminal unit which is the heart of the alarm system. The various sensors used include (1) magnetic window and door switches, (2) smoke, heat, and ultrasonic detectors, (3) infrared beams, (4) pressure pads, and (5) subscriber-activated switches (panic buttons).

The job of the cable installer may also include installation of the alarm system. Generally, the installer connects the terminal unit to the cable system and installs the sensors. When finished, the installer notifies the CATV office and performs any tests required.

The installation of the alarm wire from point to point should be done as carefully and professionally as possible. The wire used is fine and easily damaged.

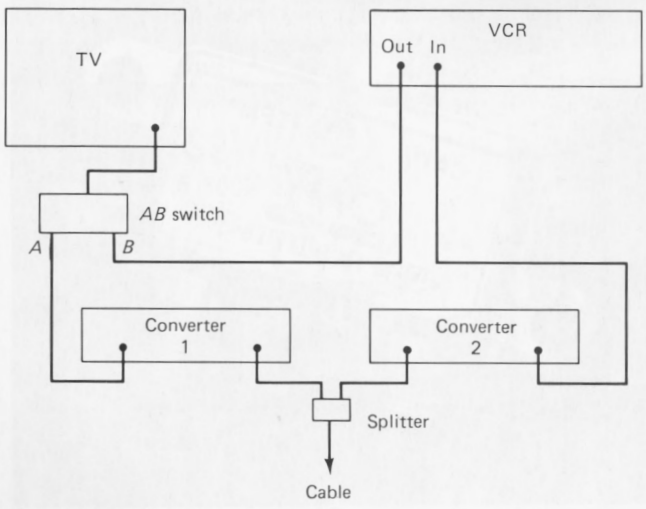


Fig. 16-18. Double-converter VCR hookup.

INSTALLATION PROBLEM SOLVING

Most problems encountered in an installation can be avoided if common sense and attention to detail, as well as periodic testing, are practiced.

Common Sense and Attention to Detail

The term *common sense* is defined as knowing the proper step or direction to take, considering all the information available. Common sense is not something that can be learned; rather it results from reasoning.

If the installation is done in a professional manner, making sure that everything is correct, there should be few problems. Attention to detail will prevent the following problems from occurring:

1. Crushed cable resulting from improper radii or overstressing
2. Short-circuited conductors from improper connector preparation or staples being driven into the cable
3. Open center conductors resulting from stretching or overstressing of the cable by ice loading or improper installation techniques
4. The entrance of moisture as a result of loose connectors or improper application of heat-shrinkable tubing or waterproofing compound

Periodic Testing

If we take signal measurements at the major points in the run, we will know whether we are experiencing problems. The major points to measure the signal level are at the tap, the ground block, the converter, and the TV set.

The following steps are recommended for the installation of drop cable using periodic testing procedures:

1. Measure the signal level at the tap with the SLM.
2. If less than enough signal is available for the drop, inform your supervisor.
3. If sufficient signal is available, make your connection at the tap and continue the cable drop to the house hook.
4. Run the cable from the house hook to the ground block.
5. Make a signal-level check at the ground block. If sufficient signal is present, continue with the cable run to the set or splitter. If insufficient, or no signal is present,

the problem is in the ground block, connectors, or that section of cable.

6. Measure the signal at the end of the cable run. If sufficient, attach to the converter.
7. After connecting a length of cable to the converter, make a signal-level measurement. If 3 to 5 dBmV of signal is available, attach the matching transformer and connect to the TV set. If the signal level is worse, suspect the converter or the short length of cable.
8. Have the subscriber turn the VHF channel selector to the channel used by the system and observe the picture. If it is acceptable, explain the operation of the hand control and answer any questions.
9. If the reception is poor, suspect the matching transformer or the TV set. If the set appeared to be functioning satisfactorily before the installation was begun, the TV set is probably not at fault. Some cable companies supply their installers with small portable TV sets (test sets, discussed earlier in this chapter) to use in this type of situation. If you have a test set, connect the cable to it first. The use of the test set initially will alert you to a problem without alarming the subscriber unnecessarily.

SUMMARY

1. Homes may be either prewired (before the home is completely built) or postwired (after the home is built) for cable service.
2. An SLM is used to determine whether enough signal is available for the drop.
3. The installer must act in a professional manner while installing cable service.
4. The factors that determine the method used to bring cable service to the subscriber are (*a*) subscriber preference, (*b*) type of home construction, (*c*) type of siding, and (*d*) location of the set(s).
5. To aid in camouflaging the cable along woodwork and doorways, white- and beige-colored jackets are available.
6. A converter is used to modify all of the cable channels so that they may be received on just one channel (either Channel 2, 3, or 4) of a TV set.
7. On some dual cable systems, an *AB* switch is used to choose which cable will supply signals to the converter.
8. The three classifications of multidwelling units are (*a*) high-rise edifices, duplex and triplex buildings, and (*c*) apartment houses.
9. In addition to cable programs, installers may also be required to install or connect (*a*) fire, burglar, and medical alert alarm systems; (*b*) FM radios; and (*c*) VCR to TV cables.
10. The qualities that an installer should exhibit are common sense, attention to detail, and the practice of periodically testing the signal level.

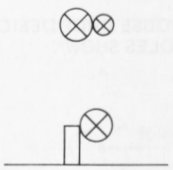
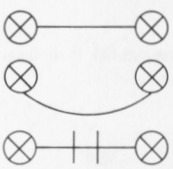
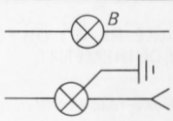
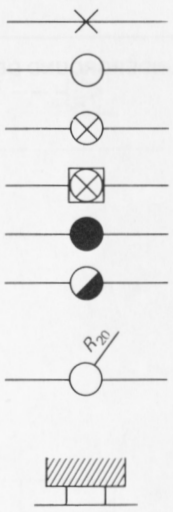
REVIEW QUESTIONS

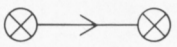
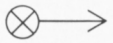
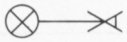
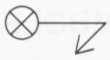
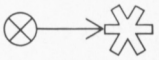
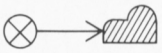
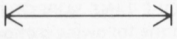
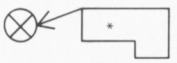
1. What two wiring methods are used for installation of CATV service?
2. What does the abbreviation VOM mean?
3. What instrument is used to measure the amount of signal on a CATV system?
4. Describe the procedure to be followed in testing a manhole for the presence of gas.
5. Name three factors that determine the method of installation of CATV service.
6. What are the three types of construction used for single-family dwellings?
7. Name three types of siding that installers find on homes.
8. What size of hole is required to accommodate a single cable bushing?
9. Why should an installer *always* drill from the inside out?
10. Describe the process of bringing CATV cable from the ground block to the TV set in a home with a basement.
11. Describe the process of bringing a cable from the basement to a wall plate.
12. What three colors of cable jacket are used for drop cables?
13. What is the function of a converter?
14. What is the function of an AB switch?
15. What is the function of an apartment box?
16. Describe the process of interconnection that allows the subscriber to tape what is being viewed on the TV set.
17. Name three types of sensors used in fire or burglar alarm systems.
18. What are the three qualities that an installer should exhibit while installing CATV service?
19. Name three ways that coaxial cable can be damaged during an installation.
20. What should you do if there is insufficient signal present at a tap?

A
APPENDIX

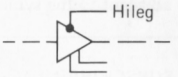
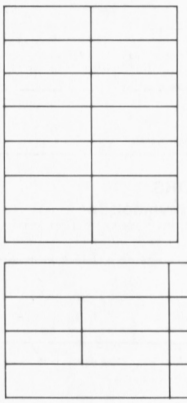
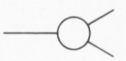
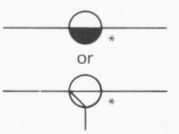
GRAPHIC SYMBOLS

SYMBOLS FOR USE IN CABLE TELEVISION

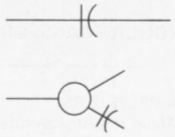
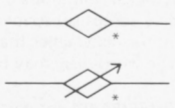
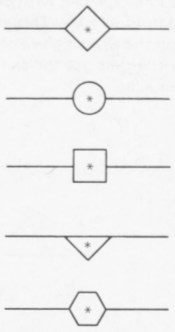
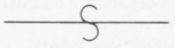
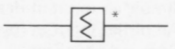
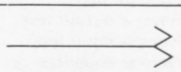
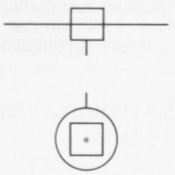
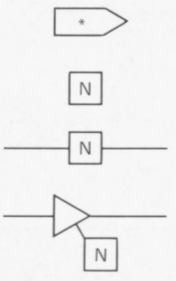
POLES Unless otherwise specified, the standard considers wooden poles. Poles of other material, are designated by letters shown within or adjacent to pole symbols. The standard states that unless otherwise specified on drawings or referenced documents, pole usage and ownership are the same. For modification, the following letters are to be shown adjacent to the pole symbol; Metallic M Concrete C Telephone T Joint J Power (Electric) P Pole ownership and conditions not covered above require appropriate designation within or adjacent to the circle.	**Power pole** **Telephone pole** **Joint usage, power and telephone pole** **With power transformer** **CATV pole** **Proposed pole** **Riser pole** Use of a number indicates vertical distance from aerial connection to ground level. **Other supporting-type structures** Show approximate structure outline or a portion thereof in this manner.	
POLE LINE SUPPORT ELEMENTS In the following section, poles are shown as joint power and telephone poles because this occurs most frequently.	**Push brace** To show a push brace, the support pole is a smaller symbol. It is proposed to be drawn in its actual supporting position relative to the pole it is bracing. **Extension arm (used by CATV)**	
CABLE SUPPORT ELEMENTS Stranded or solid messenger items with poles shown are represented by:	**Tensioned messenger wire** **Slack span, messenger wire** Tensioned messenger wire without cable (overhead guy)	
MISCELLANEOUS AS-BUILT SYMBOLS	**Bond** **Ground**	

SYMBOLS FOR USE IN CABLE TELEVISION (continued)

ANCHORING AND GUYING WITH POLES SHOWN	**Pole-to-pole guy**	
	Sidewalk down guy	
	Sidewalk down guy with anchor	
	Down guy	
	Down guy with anchor	
	Strut	
	Tree guy and anchor	
	Rock guy and anchor	
	Building guy and anchor	
UNDERGROUND DESIGNATIONS	**Underground routing—direct buried**	
	Pedestal Symbol on underground routing symbol, not cable symbol	
	Manhole See note under pedestal	
	Vault-hand hole See note under pedestal	
	Underground routing—duct line The standards for underground bore are to be used only if they are essential to show construction.	
	Direct burial of cable	
	Burial of cable in conduit	
HOUSE DROP DESIGNATIONS WITH POLES SHOWN	**Individual dwelling** Numeral indicates the number of potential house drops at this location.	
	Multiple-dwelling units Numeral indicates number of dwelling units, the arrow indicates the tap location.	
The asterisk is replaced by the proper designation.	**Nonresidential building (school, church, local organization, etc.)** Designated appropriately as to the type of building or service.	
MAKE-READY OR POLE LINE PREPARATION REQUIREMENTS *Make-ready note number	Arrangement of existing equipment on the pole must be altered for CATV installation.	

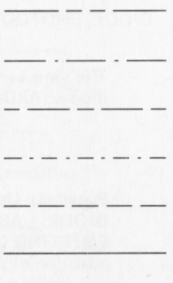
SYMBOLS FOR USE IN CABLE TELEVISION (continued)

POWER TRANSFORMER PLATFORM OR PAD		
AMPLIFIERS Again the broken line — —— — indicates line connection to a symbol and is not part of the symbol. Amplifiers on feeder lines (lines which may accept subscriber taps) should be drawn uniformly smaller than amplifiers on trunk lines. The word *hileg* may be added for clarity. Asterisks are not part of the symbols. They are to be replaced with designations to denote the amplifier type. Designations will be explained on the drawing or referenced document. Line extenders use the same symbols but are drawn smaller.	**Amplifiers** (IEC)	
	Amplifiers (feedforward)	
	Amplifier with subscriber distribution (IEC) The dot indicates high-output feeder line, if applicable.	
	Bridging amplifier with subscriber distribution (IEC)	
	Bridging amplifier with subscriber distribution and trunk termination.	
	Terminating (nonbridging) amplifier with subscriber distribution (IEC)	
AMPLIFIER IDENTIFICATION BOX Size and shape of the identification box is at the discretion of the designer. Information normally included in the identification box: Amplifier number Power supply number and power feed Ac voltage Amplifier cascade Amplifier output at design frequency Amplifier input at design frequency Amplifier input at low forward channel Forward equalizer Forward pad Reverse output level Reverse input level Reverse equalizer Reverse pad Amplifier part number Reverse part number Footage to previous amplifier	**Two Suggested Styles** (scale to fit maps) 	
SPLITTING DEVICES The word *hileg* may be added for clarity.	**Two-way splitter** (IEC)	
	Three-way splitter (IEC) Dot shows high output.	
	Four-way splitter (IEC)	
	Directional coupler (IEC) Model or value designations are to be shown adjacent to symbols. The high-loss leg leaves from the angular half of the symbol.	

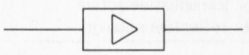
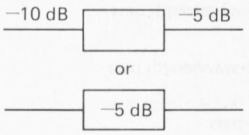
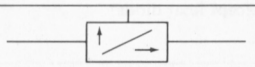
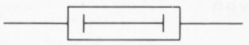
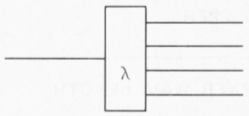
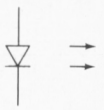
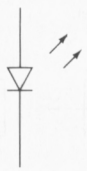
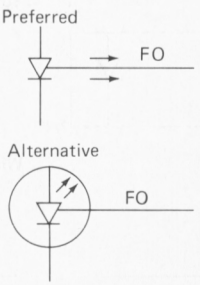
SYMBOLS FOR USE IN CABLE TELEVISION (continued)

AC POWER BLOCKS	**AC power blocks** (IEC) A two-way splitter with AC power block shown as an example of application.	
EQUALIZERS The asterisk is to be replaced with a model number or performance characteristic (value) within or adjacent to the symbol and is not part of the symbol.	**Fixed equalizer** (IEC) **Variable equalizer (IEC)**	
SUBSCRIBER TAPS NOTE: The subscriber's port blocks AC power and the asterisk will be replaced with a model number or value.	**One-output directional tap** **Two-output directional tap** **Four-output directional tap** **Six-output directional tap** **Eight-output directional tap** **Other taps** Taps with other numbers of drops and taps other than directional, e.g., pressure, should be designated by modification of these symbols or the listing of new symbols on the legend sheet for each design.	
SPLICE		
FIXED FLAT ATTENUATORS The asterisk is replaced as on symbols for equalizers and taps.	(IEC)	
LINE TERMINATIONS	**(AC power blocking unless otherwise noted.)**	
POWERING DEVICES *power supply name designator	**Cable AC power combiner** (IEC) **Power supply**	
CARRIER EQUIPMENT The symbol points in the direction of its transmission. The asterisk is not part of the symbol and will be replaced with the appropriate descriptive designation.	**Carrier control generator** (IEC) **Notch filter (narrow-band stop filter)** Application: External Application: Internal	

SYMBOLS FOR USE IN CABLE TELEVISION (continued)

SIGNAL PROCESSING LOCATIONS (Antenna site, head-end, hub, etc.)	Head-end Hub	
COAXIAL CABLES NOTE: Type should be designated by modification of these symbols or the listings of new symbols on the legend sheet for each design.	1.000 in. 0.875 in. 0.750 in. 0.625 in. 0.500 in. 0.412 in.	

SYMBOLS FOR USE IN FIBER-OPTIC SYSTEMS

AMPLIFIER, OPTICAL NOTE: Indicate the dB level.	
ATTENUATOR, OPTICAL-ELECTRICAL NOTES: 1. Arrows on cable optional. 2. Directional value specified, optional (decibel loss). 3. If decibel value specified for two-way (directional), the two attenuation values will be outside the block with an arrow pointing in the direction of the optical beam. 4. In case of one-way, the value (decibel loss) will be inside the block.	
BEAM SPLITTER	
DELAY DEVICE, OPTICAL	
DEMULTIPLEXER, WAVELENGTH	
DIODE, LASER, (ILD)	
DIODE, LIGHT EMITTING, (LED) Pigtailed	 

SYMBOLS FOR USE IN FIBER-OPTIC SYSTEMS (continued)

DIODE, LIGHT-EMITTING–PHOTODETECTOR (DETEM)

DIODE, PHOTODETECTOR

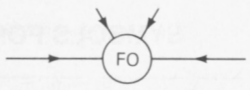
The same symbol is used for avalanche photo diodes (APD) and pin diodes.

Pigtailed: Use the symbol in the section DIODE, LASER, AND DIODE, LIGHT-EMITTING (above) except reverse direction of arrows

COUPLER

Use standard established graphic symbols of ANS1 Y32.2 for coupler in conjunction with the following:

NOTES:
1. "Tp" for transmissive passive
2. "Ta" for transmissive active
3. "Rp" for reflective passive

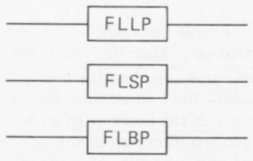


FILTERS: Above each symbol the limiting wavelengths shall be provided (in nm).

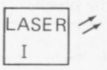
Long-wavelength pass

Short-wavelength pass

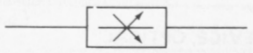
Band-pass



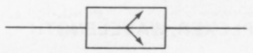
LASER (except laser diode)



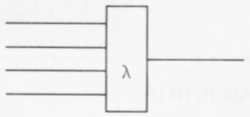
MODE MIXER



MODE STRIPPER

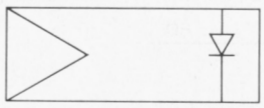


MULTIPLEXER, WAVELENGTH



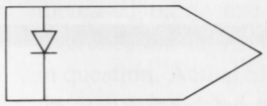
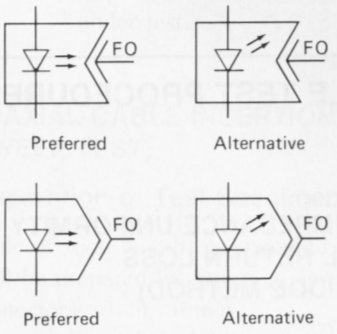
TRANSMITTER

Without pigtail source



With pigtail source

SYMBOLS FOR USE IN FIBER-OPTIC SYSTEMS (continued)

RECEIVERS	
CONNECTORS: Symbol for connectors shall be in ANS1 Y32.2 with two exceptions shown in 23.18 (a) and 23.18 (b). **Receptacle with optical source**: for optical detectors, reverse direction of arrows. **Plug with optical source**: for optical detectors, reverse direction of arrows.	

Developed and adopted by committees of the Society of Cable Television Engineers and the National Cable Television Association

B
APPENDIX

COAXIAL CABLE TEST PROCEDURES

COAXIAL CABLE IMPEDANCE UNIFORMITY AND STRUCTURAL RETURN LOSS (VARIABLE RF BRIDGE METHOD)

This procedure describes a method of determining coaxial cable impedance uniformity by means of structural return loss (SRL) versus frequency measurements. A variable RF bridge and sweep-frequency techniques are employed.

The test circuit sensitivity should allow structural return loss measurements of at least 40 dB, from 5 to 300 MHz, to be made on a nominal 75-Ω-impedance cable.

Preparation of Test Specimens

Cable of such lengths as specified shall be prepared by fitting cable ends with either standard connectors or slip fittings.

Method

Equipment

1. Sweep generator
2. Electronic switch
3. RF amplifier
4. Detector
5. Variable bridge
6. Reference attenuator
7. Variable termination
8. Interconnecting cables (as required)
9. Oscilloscope (10 mV, 2MHz minimum)
10. Root-mean-square voltmeter

Procedure

1. Calibration (method A—calibrated mismatch)
   a. Connect test equipment as shown in Fig. B-1.
   b. Turn power switches on and allow a 10-minute warm-up.
   c. Set oscilloscope sensitivity to 10 mV (vertical) and adjust the horizontal gain to fill the screen of the scope.
   d. Adjust the sweep width control to display from 5 to 300 MHz.

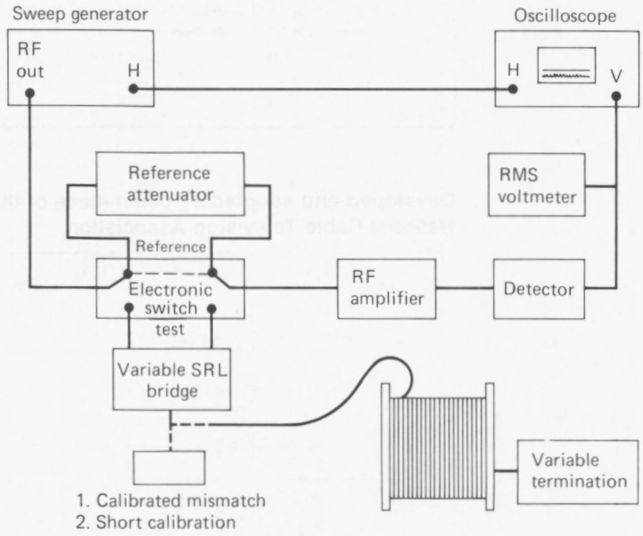


Fig. B-1

   e. Adjust the intensity of the oscilloscope and focus controls for a sharp trace.
   f. Set the reference attenuator for 30 dB and place a 30-dB calibrated mismatch on the bridge test port.
   g. Set the bridge to 75 Ω and adjust the bridge capacitor for coincidence with the reference trace.
2. Calibration (method B—short-circuited reflection)
   a. Complete steps *a* to *e* above.
   b. With the bridge test port short-circuited (100 percent reflection, zero-decibel return loss), adjust the reference attenuation for 0 dB and note that the traces coincide.
   c. Place 30 dB in the reference path and proceed with the test procedure.
3. Measurement technique (general—observe Fig. B-1)
   a. The bridge used for this measurement should be equipped with both resistance and capacitance adjustments, allowing the bridge to be matched to the average cable characteristic impedance. The bridge and the far-end termination balance are then adjusted for a minimum rms voltmeter reading.

b. Since most detector-attenuator systems are unable to respond fully to fast rise-time spikes (very-high-frequency spikes), proper system response is assured when either sweep width or sweep speed of the system is reduced to permit maximum detector response and output (greatest average structural return loss).

c. With sweep controls set for full-scale display of 5 to 300 MHz and the RF switch set to display only the SRL pattern, adjust the variable bridge arms and the variable far-end termination controls for a minimum rms meter indication. Properly accomplished, minimums in the displayed trace touch the base reference line. Incorrect readings may be obtained if these adjustments are made to display minimum SRL spike indication without baseline consideration.

d. SRL measurement—reduced sweep width

i. Without disturbing the variable bridge and terminator settings, reduce the sweep width to no more than 10 MHz for a full horizontal scale scope indication. With the FREQUENCY control, manually move the observed 10-MHz sweep segment so that the entire 5- to 300-MHz range is displayed on the scope in sequence. If any observed peaks closely approach the 30-dB calibrated reference line established in the calibration procedure, further reduce sweep width to make sure that no further detector response is possible.

ii. If maximum reflections observed in the preceding paragraph do not exceed the reference trace, the cable under test has better than a 30-dB structural return loss for the frequency range of 5 to 300 MHz. To measure the actual level of maximum reflections, observe instructions in the preceding paragraph and center each major reflection in question on the scope with reduced sweep width. The reference attenuator is either increased or decreased to move the calibrated reference line into coincidence with the reflection in question. Actual SLR for that reflection is then the value indicated by the reference loss attenuator setting.

iii. Repeat the above for the other end of the cable under test.

e. SRL measurement—reduced sweep speed

i. Repeat the preceding steps without disturbing the variable bridge and terminator settings, then reduce the sweep speed (while maintaining a full 5- to 300-MHz display) until the observed test trace has been maximized, assuring complete detector response.

ii. If the maximum reflections observed in the preceding paragraph do not exceed the reference trace, the cable under test has better than 30 dB of structural return loss for the frequency range of 5 to 300 MHz. To measure the actual level of maximum reflections, observe the instructions of the preceding paragraph and center each major reflection in question on the scope with reduced sweep width. The reference attenuator is either increased or decreased to move the calibrated reference line into coincidence with the reflection in question. Actual SRL for that reflection is then the value indicated by the reference loss attenuation setting.

iii. Repeat the above for the other end of the cable under test.

COAXIAL CABLE INSERTION LOSS (SWEEP TEST)

Preparation of Test Specimens

Cable of such lengths as specified by order or specification shall be prepared by fitting cable ends with either standard connectors or slip fittings.

Method

Equipment

1. Sweep generator
2. Electronic switch
3. RF amplifier
4. Detector
5. Reference attenuator
6. Oscilloscope (10-mV, 2-MHz minimum bandwidth)
7. Interconnecting cables and cable connectors as required
8. Oscilloscope amplifier (if required)

Procedure

1. Connect the equipment as shown in Fig. B-2.
2. Turn the power switch on and allow 10-min warm-up. Adjust the scope controls for a clear, sharp trace.

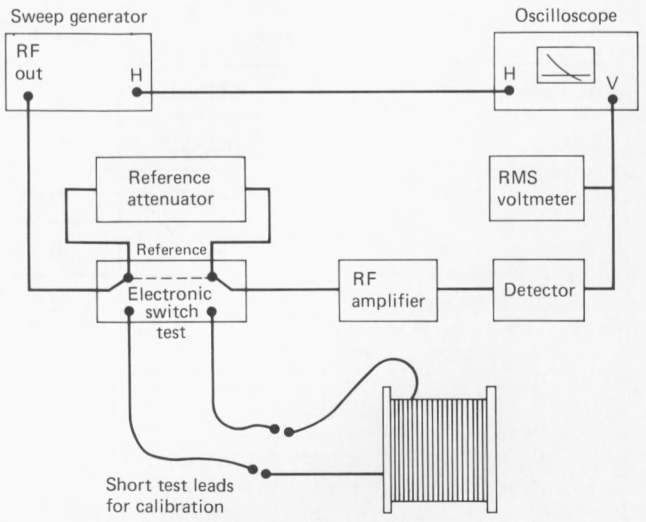


Fig. B-2

3. Set the sweep width control and center frequency control on the oscilloscope to display the range of measurement desired on the face of the scope.
4. Short-circuit the cables coming from the switcher, using the appropriate type of short-circuiting adapter.
5. Turn the reference attenuator to 0-dB loss and ensure that both the reference and test traces coincide.

NOTE: Adjustments may be made on the scope amplifier vertical controls or the RF output of the sweep generator to obtain an "on-screen" trace.

6. Remove the short-circuiting adapter used in step 4 above and connect the leads from the switcher to the prepared ends of the cable under test.
7. Using the Reference attenuator, reestablish the coincidence of the traces at the frequency of interest. The generator sweep width control, center frequency, and fixed markers may be used to establish the frequency at the point of coincidence.
8. If needed, the RF output power may be increased to obtain a precise measurement at higher frequencies. The vertical amplifier of the oscilloscope may also be used to increase the sensitivity of the measurement.
9. Record the attenuator setting and frequency at the point(s) of coincidence.

Calculations

Attenuation is directly proportional to length and conversion to decibels per 100 ft is given by

$$\text{Attenuation in dB/100 ft} = \frac{100 \times \text{attenuation (dB/ft)}}{L}$$

C
APPENDIX

CATV CHANNEL DATA

Channel	Frequency in MHz	Carriers, MHz		
		Video	Color	Sound
Subchannels				
T_7	5.75–11.75	7	10.58	11.5
T_8	11.75–17.75	13	16.58	17.5
T_9	17.75–23.75	19	22.58	23.5
T_{10}	23.75–29.75	25	28.58	29.5
T_{11}	29.75–35.75	31	34.58	35.5
T_{12}	35.75–41.75	37	40.58	41.5
T_{13}	41.75–47.75	43	46.58	47.5
	107.3 MHz	*Polling*		
	T_9	*Alarm*		
Standard channels				
2	54–60	55.25	58.83	59.75
3	60–66	61.25	64.83	65.75
4	66–72	67.25	70.83	71.75
5	76–82	77.25	80.83	81.75
6	82–88	83.25	86.83	87.75
	106.5	Addressable carrier		
	107.3	Security carrier (polling)		
	107.7	Playcable carrier		
7	174–180	175.25	178.83	179.75
8	180–186	181.25	184.83	185.75
9	186–192	187.25	190.83	191.75
10	192–198	193.25	196.83	197.75
11	198–204	199.25	202.83	203.75
12	204–210	205.25	208.83	209.75
13	210–216	211.25	214.83	215.75
Midbands				
14	120–126	121.25	124.83	125.75
15	126–132	127.25	130.83	131.75
16	132–138	133.25	136.83	137.75
17	138–144	139.25	142.83	143.75
18	144–150	145.25	148.83	149.75
19	150–156	151.25	154.83	155.75
20	156–162	157.25	160.83	161.75
21	162–168	163.25	166.83	167.75
22	168–174	169.25	172.83	173.75
Superbands				
23	216–222	217.25	220.83	221.75
24	222–228	223.25	226.83	227.75
25	228–234	229.25	232.83	233.75
26	234–240	235.25	238.83	239.75
27	240–246	241.25	244.83	245.75
28	246–252	247.25	250.83	251.75
29	252–258	253.25	256.83	257.75
30	258–264	259.25	262.83	263.75
31	264–270	265.25	268.83	269.75

Channel	*Frequency, MHz*	*Carriers, MHz*		
		Video	*Color*	*Sound*
32	270–276	271.25	274.83	275.75
33	276–282	277.25	280.83	281.75
34	282–288	283.25	286.83	287.75
35	288–294	289.25	292.83	293.75
36	294–300	295.25	298.83	299.75
Hyperbands				
37	300–306	301.25	304.83	305.75
38	306–312	307.25	310.83	311.75
39	312–318	313.25	316.83	317.75
40	318–324	319.25	322.83	323.75
41	324–330	325.25	328.83	329.75
42	330–336	331.25	334.83	335.75
43	336–342	337.25	340.83	341.75
44	342–348	343.25	346.83	347.75
45	348–354	349.25	352.83	353.75
46	354–360	355.25	358.83	359.75
47	360–366	361.25	364.83	365.75
48	366–372	367.25	370.83	371.75
49	372–378	373.25	376.83	377.75
50	378–384	379.25	382.83	383.75

Channel	*Frequency in MHz*	*Carriers, MHz*		
		Video	Color	Sound
51	384–390	385.25	388.83	389.75
52	390–396	391.25	394.83	395.75
53	396–402	397.25	400.83	401.75
62	402–408	403.25	406.83	407.75
63	408–414	409.25	412.83	413.75
64	414–420	415.25	418.83	419.75
65	420–426	421.25	424.83	425.75
66	426–432	427.25	430.83	431.75
67	432–438	433.25	436.83	437.75
68	438–444	439.25	442.83	443.75
69	444–450	445.25	448.83	449.75
Miscellaneous Channels				
54	72– 78	73.25	76.83	77.75
55	78– 84	79.25	82.83	83.75
56	84– 90	85.25	88.83	89.75
57	90– 96	91.25	94.83	95.75
58	96–102	97.25	100.83	101.75
59	102–108	103.25	106.83	107.75
60	108–114	109.25	112.83	113.75
61	114–120	115.25	118.83	119.75

*Velocity of RF in free space—984.25 ft/μs

CATV Channel Frequencies, Standard System†

Channel	*Picture Carrier*	*Crystal*	*Crystal Multiplier*	*Channel*	*Picture Carrier*	*Crystal*	*Crystal Multiplier*
T_7	7.0	52.75	×1	2	55.25	101.0	×1
T_8	13.0	58.75	×1	3	61.25	107.0	×1
T_9	19.0	64.75	×1	4	67.25	113.0	×1
T_{10}	25.0	70.75	×1	5	77.25	123.0	×1
T_{11}	31.0	76.75	×1	6	83.25	129.0	×1
T_{12}*	37.0	155.75/73	×1/×1	7	175.25	110.5	×2
T_{13}*	43.0	161.75/73	×1/×1	8	181.25	113.5	×2
T_{14}*	49.0	167.75/73	×1/×1	9	187.25	116.5	×2
				10	193.25	119.5	×2
				11	199.25	122.5	×2
				12	205.25	125.5	×2
				13	211.25	128.5	×2

*Two crystals required for double conversion.
†Crystal frequencies required to convert channel frequency to IF or IF to channel frequency.

CATV Channel Frequencies,* Incrementally Related Carriers				CATV Channel Frequencies,* Harmonically Related Carriers			
Channel	*Picture Carrier*	*Crystal*	*Crystal Multiplier*	*Channel*	*Picture Carrier*	*Crystal*	*Crystal Multiplier*
VHF							
2 I	55.25	101.0	×1	2 H	54	99.75	×1
3 I	61.25	107.0	×1	3 H	60	105.75	×1
4 I	67.25	113.0	×1	4 H	66	111.75	×1
7 I	175.25	110.5	×2	7 H	174	109.875	×2
9 I	187.25	116.5	×2	9 H	186	115.875	×2
11 I	199.25	122.5	×2	12 H	204	124.875	×2
13 I	211.25	128.5	×2	13 H	210	127.875	×2
Midband							
15 I (B)	127.25	173.0	×1	15 H	126	171.75	×1
17 I (D)	139.25	185.0	×1	17 H	138	183.75	×1
19 I (F)	151.25	98.5	×2	19 H	150	97.875	×2
21 I (H)	163.25	104.5	×2	21 H	162	103.875	×2

CATV Channel Frequencies,* Incrementally Related Carriers				CATV Channel Frequencies,* Harmonically Related Carriers			
Channel	*Picture Carrier*	*Crystal*	*Crystal Multiplier*	*Channel*	*Picture Carrier*	*Crystal*	*Crystal Multiplier*
Superband							
23 I (J)	217.25	131.5	×2	23 H	216	130.875	×2
25 I (L)	229.25	137.5	×2	25 H	228	136.875	×2
27 I (N)	241.25	143.5	×2	27 H	240	142.875	×2
29 I (P)	253.25	149.5	×2	29 H	252	148.875	×2
31 I (R)	265.25	155.5	×2	31 H	264	154.875	×2
33 I (T)	277.25	161.5	×2	33 H	276	160.875	×2
35 I (V)	289.25	167.5	×2	35 H	288	166.875	×2
Hyperband							
37 I	301.25	173.5	×2	37 H	300	172.875	×2
39 I	313.25	179.5	×2	39 H	312	178.875	×2
41 I	325.25	92.75	×4	41 H	324	92.4375	×4
43 I	337.25	95.75	×4	43 H	336	95.4375	×4
45 I	349.25	98.75	×4	45 H	348	98.4375	×4
47 I	361.25	101.75	×4	47 H	360	101.4375	×4
49 I	373.25	104.75	×4	49 H	372	104.4375	×4
51 I	385.25	107.75	×4	51 H	384	107.4375	×4
53 I	397.25	110.75	×4	53 H	396	109.4375	×4
63 I	409.25	113.75	×4	63 H	408	113.4375	×4
65 I	421.25	116.75	×4	65 H	420	116.4375	×4
67 I	433.25	119.75	×4	67 H	432	119.4375	×4
69 I	445.25	122.75	×4	69 H	444	122.4375	×4
Miscellaneous Channels							
55 I	79.25	125.0	×1	55 H	78	123.75	×1
57 I	91.25	149.0	×1	57 H	90	135.75	×1
59 I	103.25	137.0	×1	59 H	102	147.75	×1
61 I	155.25	161.0	×1	61 H	114	159.75	×1

*For unlisted channels:
2× multipliers—subtract 3MHz from crystal frequency of adjacent higher channel.
4× multipliers—subtract 1½ MHz from crystal frequency of adjacent higher channel.

Decibel-to-Voltage Conversion Chart*

For +dBmV		*For −dBmV*	
dBmV	*Millivolts*	*dBmV*	*Microvolts*
0	1.00	0	1000
+ 1	1.12	− 1	891
+ 2	1.26	− 2	794
+ 3	1.41	− 3	708
+ 4	1.59	− 4	631
+ 5	1.78	− 5	562
+ 6	2.00	− 6	501
+ 7	2.24	− 7	447
+ 8	2.51	− 8	398
+ 9	2.82	− 9	355
+10	3.16	−10	316
+11	3.55	−11	282
+12	3.98	−12	251
+13	4.47	−13	224
+14	5.01	−14	200
+15	5.62	−15	178
+16	6.31	−16	159
+17	7.08	−17	141
+18	7.94	−18	126
+19	8.91	−19	112
+20	10.00	−20	100

*Reference: 0 dBmV = 1 mV as measured across 75 Ω load.

Composite Triple Beat*

Channel	*12*	*21*	*35*	*52*	*60*
2	12	36	152	435	615
3	15	42	171	456	640
4	12	42	180	473	661
5	8	17	31	48	56
6	8	17	31	48	56
7	10	84	342	788	1048
8	16	83	345	800	1064

Composite Triple Beat*

Channel	*12*	*21*	*35*	*52*	*60*
9	18	81	348	811	1079
10	19	79	349	821	1093
11	18	75	350	830	1106
12	16	70	349	838	1118
13	10	61	348	845	1129
14		71	274	644	868
15		78	288	666	894
16		82	299	686	918
17		84	308	703	939
18		85	316	720	965
19		85	323	735	979
20		85	329	750	998
21		85	324	763	1015
22		85	328	776	1032
23			345	851	1139
24			342	856	1148
25			337	860	1156
26			332	863	1163
27			326	865	1169
28			321	866	1174
29			315	866	1178
30			309	865	1181
31			301	863	1183
32			293	860	1184
33			283	856	1184
34			273	851	1183
35			260	845	1181
36			245	838	1178
37				830	1174
38				821	1169
39				811	1163
40				800	1156

Composite Triple Beat*

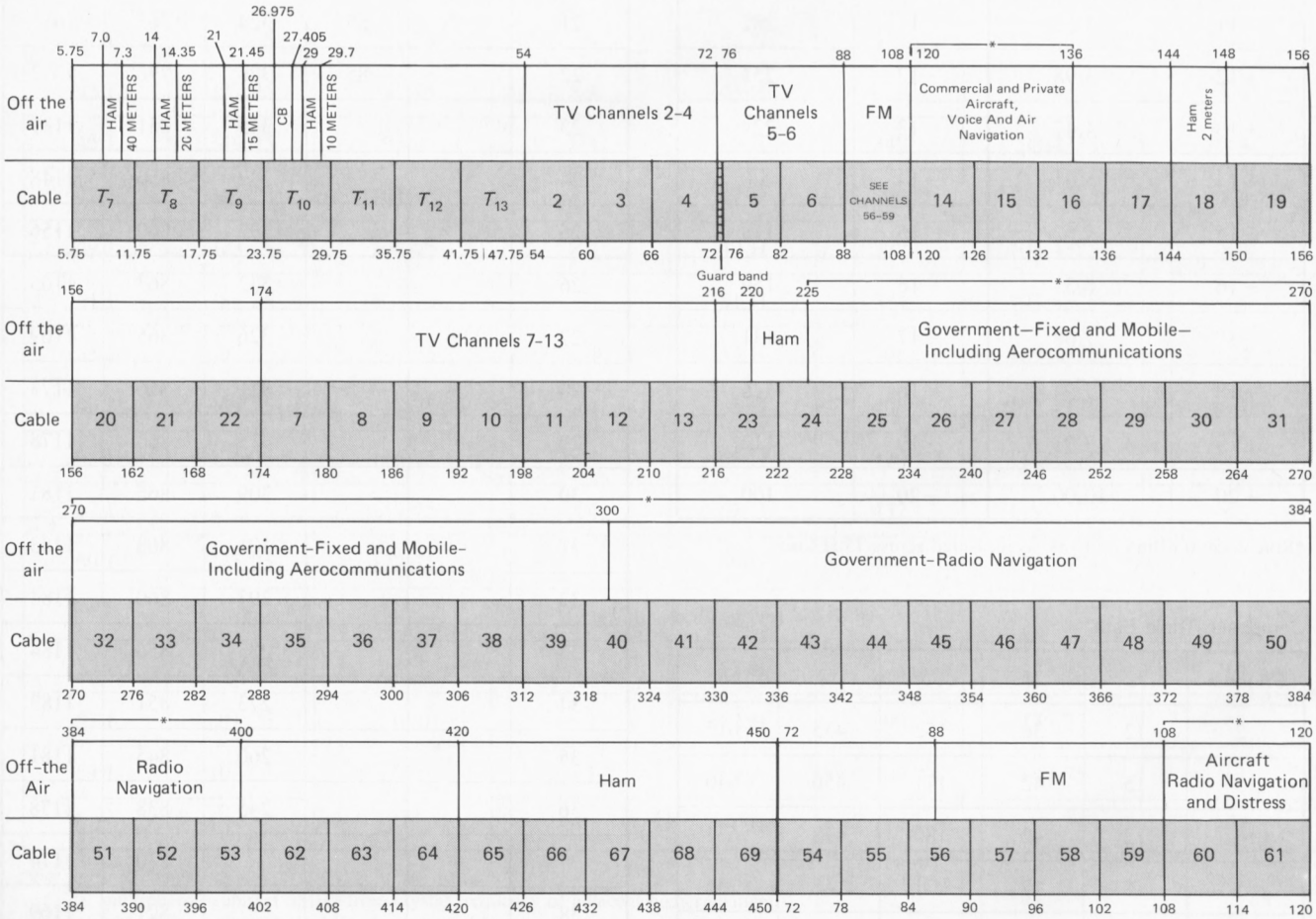
Channel	*12*	*21*	*35*	*52*	*60*
41				788	1148
42				775	1139
43				761	1129
44				747	1118
45				733	1106
46				719	1093
47				704	1079
48				688	1064
49				671	1048
50				653	1031
51				634	1013

Composite Triple Beat*

Channel	*12*	*21*	*35*	*52*	*60*
52				613	995
53					977
54					959
55					940
56					920
57					899
58					877
59					854
60					829
61					801

*$A + B - C = D$
$2A - B = D$

CATV Frequency Spectrum



*Operators of all CATV systems must notify FCC annually of all signals carried in these frequency bands.

Note: All frequences shown are in Megahertz.

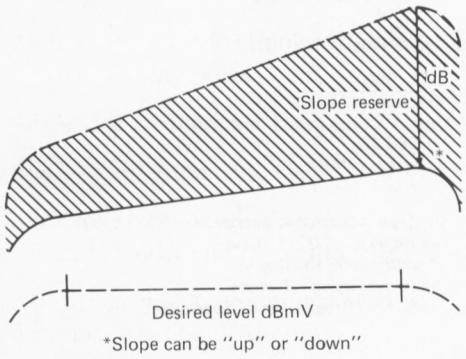
	CATV bands
T_7-T_{13}	Subchannels
2-13	Standard channels
14-22	Midband
23-36	Superband
37-69	Hyperbands
54-61	Miscellaneous

Manual Slope Control Settings vs. Temperature

Ambient Temperature		*Manual Slope Control Settings*		
°F	*°C*	*220 MHz*	*270 MHz*	*300, 400 MHz*
+125	+51.5	1 dB	1 dB	1 dB
+ 95	+35	1.5 dB	2 dB	1.5 dB
+ 70	+21	2.5 dB	3 dB	2.5 dB
+ 50	+10	3.5 dB	4 dB	3.5 dB
+ 30	−1	4.5 dB	5 dB	4.5 dB
+ 10	−12	5.0 dB	6 dB	5.0 dB
− 5	−20.5	6.0 dB	7 dB	6.0 dB
− 20	−29	7.0 dB	8 dB	7.0 dB

1. Ambient temperature is the temperature at the time and location of station. For intermediate temperatures, please interpolate.
2. Manual slope settings are given for the highest video carrier used in the system (Channels 12, 31, 36, or 53), and the dB numbers are reductions from maximum control settings.

Estimate the ambient temperature and reduce manual slope per chart.



*Slope can be "up" or "down"

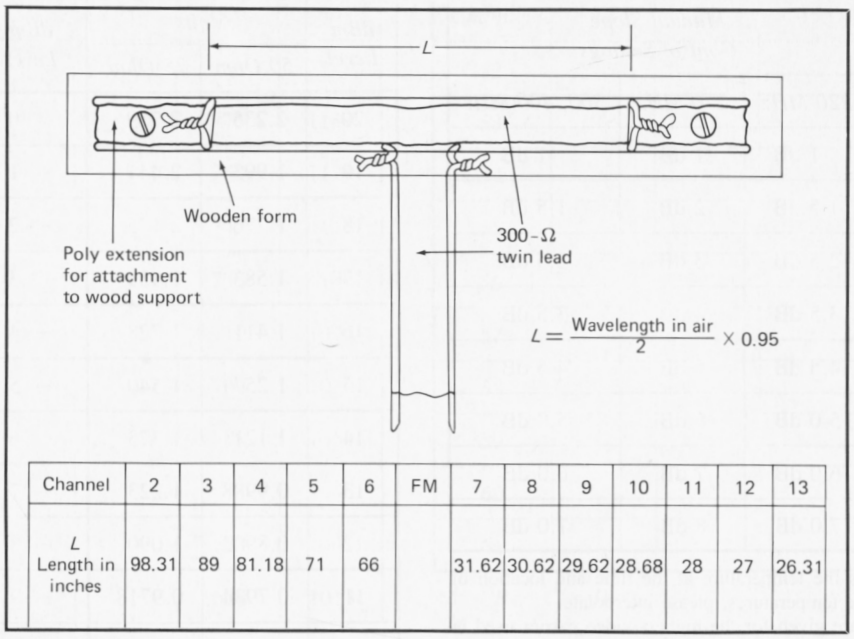
CATV System Standards
(For No Noticeable Degradation)

Signal Level to Subscribers	0 to 10 dBmV
Signal to Noise Ratio	43 dB
Signal to Composite Triple Beat	51 dB
Signal to Hum Modulation	40 dB
System Response	± 1½ dB within any channel
Signal to Beat Interference	60 dB
Signal to Reflections	40 dB
Radiation (Within FCC Specifications)	Less than 20 uv/m low band and 50 uv/m high band on a tuned dipole at 10 feet.

dBm to Voltage: Conversion Chart

dBm Level	*Volts*		*dBm Level*	*Volts*	
	50 Ohm	*75 Ohm*		*50 Ohm*	*75 Ohm*
20	2.235	2.739	0	0.2236	0.2739
19	1.993	2.441	− 1	0.1993	0.2441
18	1.776	2.175	− 2	0.1776	0.2175
17	1.583	1.939	− 3	0.1583	0.1939
16	1.411	1.728	− 4	0.1411	0.1728
15	1.257	1.540	− 5	0.1257	0.1540
14	1.121	1.373	− 6	0.1110	0.1373
13	0.9988	1.223	− 7	0.0999	0.1223
12	0.8902	1.090	− 8	0.0892	0.1090
11	0.7934	0.9718	− 9	0.0792	0.0972
10	0.7071	0.8660	−10	0.0707	0.0866
9	0.6302	0.7719	−11	0.0630	0.0772
8	0.5617	0.6879	−12	0.0562	0.0688
7	0.5060	0.6132	−13	0.0506	0.0613
6	0.4461	0.5465	−14	0.0446	0.0547
5	0.3976	0.4870	−15	0.0398	0.0487
4	0.3594	0.4340	−16	0.0359	0.0434
3	0.3158	0.3869	−17	0.0316	0.0387
2	0.2815	0.3448	−18	0.0282	0.0345
1	0.2508	0.3073	−19	0.0251	0.0307
0	0.2236	0.2739	−20	0.0224	0.0274

CONSTRUCTION OF 300-OHM, REFERENCE-FOLDED DIPOLE



Channel	2	3	4	5	6	FM	7	8	9	10	11	12	13
L Length in inches	98.31	89	81.18	71	66		31.62	30.62	29.62	28.68	28	27	26.31

Rules of thumb

1. To calculate the change in attenuation of a cable relative to temperature:

   ΔATT = 1% for each 10°F of change

2. To calculate the attenuation of a cable if the attenuation at one frequency is known:

   $$\Delta ATT = \sqrt{\frac{f_1}{f_2}}$$

   Where:

   ΔATT = change in attenuation

   f_1 = first frequency

   f_2 = second frequency

3. Input to trunk module should approximate noise figure (NF).

Useful information

Inch = 2.54 centimeters
Foot = 0.3048 meters
Mile = 1.609 kilometers
Statute mile = 0.8684 nautical miles

Millisecond = 1/1000 s.
Microsecond = 1/1000,000 s.
Nanosecond = 1/1,000,000,000 s.
Kilohertz = 1000 X hertz
Megahertz = 1,000,000 X hertz
Gigahertz = 1,000,000,000 X hertz

Useful equations

Wavelength in meters (air) = $\frac{300}{\text{Frequency, MHz}}$

Wavelength in feet (air) = $\frac{984.25}{\text{Frequency, MHz}}$

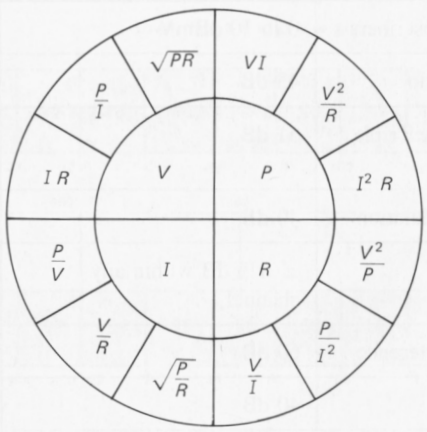
Temperature conversion

$F^\circ = C^\circ \times \frac{9}{5} + 32$

E_f (field intensity in microvolts per meter) = 0.021E (field-strength meter reading in microvolts using reference dipole) X f (frequency in megahertz)

UHF Channels 14-83
Frequencies 470-890 MHz

Ohm's law wheel



P—power in watts *I*—current in amperes
V—voltage in volts *R*—resistance in ohms

GLOSSARY OF CATV TERMS

AB Switch—A coaxial cable switch used to select which input signal will appear at its output connector.

Access Channels—Channels reserved by a cable company for the exclusive use of the community.

Active Device—An electronic circuit that amplifies or controls signals (see also "Passive Device").

Addressability—The ability to provide specific programming to an individual subscriber.

Adjacent Channel—A TV channel immediately above or below the channel in question.

Adjacent-Channel Interference—Interference caused by the carrier of an adjacent channel beating with a carrier of the desired channel.

Aerial Cable—See "Aerial Plant."

Aerial Plant—CATV trunk and distribution cable supported on utility poles.

AFC—See "Automatic Frequency Control."

AGC—See "Automatic Gain Control."

Agile Receiver—A satellite receiver able to be tuned to any transponder on the satellite (see "Fixed Receiver").

Alarm System—A system that signals the presence of an abnormal condition. Alarm systems are used to indicate fire, burglary, and medical emergencies.

Alignment—The process of adjusting an electronic circuit to obtain maximum performance.

Allocations, Frequency—A group of frequencies devoted to a specific use or service.

Alphanumeric—Data containing either letters and numbers or symbols.

Alternating Current (AC)—A flow of electricity that reaches a maximum value in one direction, decreases to zero, and then reaches a maximum value in the other direction.

AM—See "Amplitude Modulation."

Ammeter—An instrument used to measure electric current flow in amperes, milliamperes, or microamperes.

Ampere—The basic unit of current flow. An ampere is the amount of electron flow that results from the application of 1 V to a resistance of 1 Ω.

Amplification—The process by which the strength of a signal is increased.

Amplifier—An electronic device used to increase the strength of a signal.

Amplitude Modulation—The process of causing the amplitude of a carrier wave to vary with variations in the modulating signals.

AM Transmitter—A transmitter that transmits an amplitude-modulated (AM) carrier wave.

Anchor—A device that holds something securely. For example, a buried anchor holds a utility pole when a technician fastens a guy wire between it and the pole.

Antenna—A device used to radiate or receive electromagnetic energy.

Antenna Gain—The measure of the effectiveness of an antenna compared to that of a reference antenna.

Antenna Polarization—The characteristic of an antenna that allows electromagnetic energy to be radiated or received in either a horizontal or a vertical direction.

Antenna Preamplifier—An amplifier placed close to an antenna to amplify weak signals before they experience losses in the transmission line.

Antenna System—All parts of the transmission system from transmitter to antenna. A collection of antennas.

Apartment Box—A locked sheetmetal enclosure containing both the active and passive CATV devices used in a multidwelling.

APD—See "Avalanche Photodiode."

Armored Cable—A type of coaxial cable used in wet environments. To construct armored cable, bare cable is coated with a flooding compound and jacketed. Over this jacket a steel armor and flooding compound are applied, and a second jacket is placed over the entire assembly.

ASC—See "Automatic Slope Control."

ASG—See "Automatic Slope and Gain."

Attenuation—A reduction of signal strength. Attenuation results from the passage of a signal through a transmission line or may be introduced intentionally.

Attenuator—A device to reduce the strength of a signal.

Audio—The sound portion of the television signal.

Automatic Frequency Control (AFC)—A circuit designed to maintain the frequency of an oscillator automatically.

Automatic Gain Control (AGC)—A circuit designed to maintain a fixed level of amplification (gain) of a signal.

Automatic Slope Control (ASC)—A circuit designed to maintain a given ratio of amplification to the high and low channels used in CATV amplifiers.

Avalanche Photodiode—A device used to receive the modulated signal on fiber-optic cable.

Backfill—The material (usually soil and rocks) used to fill up a hole or a trench.

Back-Pull Route—A method of cable construction where the cable reel is stationary and the cable is pulled into place.

Balun—A device used for matching an unbalanced transmission line to a balanced one. The device used to match the impedance of coaxial cable to that of twin lead.

Band-Pass Filter—An electronic circuit that allows a band of frequencies to pass with little attenuation but offers substantial attenuation to all other frequencies.

Band-Reject Filter—An electronic circuit that offers greater attenuation to a band of frequencies but little attenuation to all other frequencies.

Bandwidth—The upper and lower frequency limits of a band of frequencies.

Baseband—The frequency band used in a signal distribution system. All the channels used by a CATV system.

Basic Cable Service—The full complement of services and signals offered to a cable subscriber excluding Premium service.

Beam (Electromagnetic)—A concentrated stream of electromagnetic energy emanating from an antenna.

Bird—A slang term for a satellite.

Block Converter—An electronic device that changes (converts) a group of satellite signals to either a lower or a higher frequency.

Body Belt—A belt (usually leather) worn by workers who climb utility poles. This belt has loops for tools and two large rings (D rings) for the attachment of the safety strap.

Bonding—The grounding of strand cable to prevent build-up of static charges.

Bore Pit—A pit dug along the route of an underground cable installation to allow the placement of a boring machine or a rod pusher.

Bridging Amplifier or Bridger—An amplifier used to provide additional amplification for feeder line signals. Usually part of a trunk station.

Broadband—A term used to describe an amplification system that maintains a flat response over a wide range of frequencies.

Broadcasting—The process of sending electromagnetic signals into the air for reception by antenna systems.

Cablecasting—The sending of original programming over a cable system.

Cable Distribution System—All the active and passive devices used to deliver CATV signals from the head-end to the subscriber.

Cable Powering—The method of supplying power to the various amplifiers used in the cable distribution system.

Cable Service Representative—An individual who represents the cable system and either answers subscribers' questions, sells advertising space on the cable, or acts in a public relations capacity.

Cable System Maps—Street maps of the franchise area that contain the location of poles and active and passive devices as well as the distance between them. Cable system maps are used in troubleshooting a malfunctioning system.

Cable TV—A communication system that gathers local, remote, and satellite signals and sends them by coaxial cable to subscribers.

Carrier Wave—The electromagnetic wave produced by a transmitter, with or without modulation (see "Continuous Wave").

Carrier-to-Noise Ratio—The ratio of the carrier's magnitude to that of the noise.

CARS (Community Antenna Relay Service)—A system which allows CATV signals to be transmitted from head-end to hub or antenna site to head-end.

CATV—Originally the acronym for community antenna television; now the acronym for cable television.

CATV Technician—An individual who installs, repairs, aligns, or maintains a CATV system.

Channel—A band of frequencies, 6 MHz wide, that contains all the audio, video, synchronizing, and color information of a television signal.

Channel Capacity—The total number of channels used by a CATV system.

Characteristic Impedance—The impedance of a transmission line, determined by capacitance, inductance, and resistance.

Climbing Space—The amount of space allotted on a util-

ity pole that is free from obstructions. The climbing space is generally 30 in. sq.

C/N—See "Carrier-to-Noise Ratio."

Coaxial Cable—A transmission line characterized by a conductor within a hollow conductor, each having the same axis.

Co-channel—The presence of two television stations on the same channel.

Co-channel Interference—Interference by another signal on the same channel as the desired signal, usually seen as horizontal or vertical lines across the picture.

Combiner—See "Signal Combiner."

Communications Satellite—An orbiting satellite that receives and rebroadcasts radio and television signals.

Community Antenna Television—A communication system that utilizes coaxial cable to furnish subscribers with television signals obtained from a master antenna.

Composite Triple Beat—A large number of triple beats being amplified together and producing interference on a CATV system.

Construction Tools—The various hand and power tools used in the construction of a CATV system.

Continuous Wave—An electromagnetic wave that maintains a constant amplitude and frequency.

Converter—A device used to change (convert) signals on the cable from a higher frequency to a standard television channel, usually Channel 3.

Current—The flow of electrons under the influence of voltage. Current is measured in amperes, milliamperes, and microamperes.

CW—See "Continuous Wave."

Data—Symbols, numbers, or letters used to convey information.

dBmV—Gain or loss in decibels referenced to 1 mV across 75 Ω of impedance.

DBS—See "Direct-Broadcast Satellite."

dBW—Decibels referenced to 1 W.

Decibel, dB—The standard unit for expressing gain or loss as well as relative power levels of signals.

Demodulate—The process of removing the modulation (intelligence) from a carrier wave.

Demodulator—A device for removing the modulation (intelligence) from a carrier wave.

Demultiplexer—A device used to separate two or more signals that were previously multiplexed (mixed).

Dielectric—The insulating material between the inner and outer conductors in coaxial cable.

Digging Tools—Tools, both hand and power, used to dig holes for utility poles, trenches for buried cable, or for digging bore pits for boring machines and rod pushers.

Diplexer—An electronic device that allows more than one transmitter to operate simultaneously on the same antenna.

Dipole Antenna—An electromagnetic radiator, often center-fed, used to receive or radiate electromagnetic energy.

Direct-Broadcast Satellite—A system in which ground stations broadcast their signals to orbiting satellites who in turn rebroadcast directly to subscribers.

Direct Current—A flow of electrons in one direction that does not vary appreciably from a given value.

Directional Coupler—A passive device that provides a low-loss tap leg for coupling signals from a trunk or feeder line.

Dish—See "Parabolic Reflector."

Distribution Amplifier—See "Line-Extender Amplifier."

Distribution System—In CATV, a network of trunk, feeder, and subscriber lines that, along with active and passive devices, distribute programming to subscribers.

Down-Conversion—The process of reducing the satellite frequencies to a VHF frequency that may be used in a CATV system.

Down Converter—A device that changes an incoming frequency to a lower one.

Downlink—The signals from the satellite to the ground stations (see "Uplink").

Downstream—The signals from the head-end to the subscribers of a CATV system.

Drip Loop—A loop in the subscriber drop cable to prevent rain from following the cable and entering a device or the subscriber's home.

Drop—See "House Drop."

Drive-off Route—A method of cable construction where the cable is secured at a pole and the reel trailer is pulled behind a vehicle.

Drop Cable—A small-diameter coaxial cable used to connect the subscriber to a feeder line.

Dual Cable—Two subscriber drop cables joined together by a common jacketing material. Dual cable is used in systems carrying more than 50 channels.

Earth Station—A ground facility that utilizes an antenna and electronic equipment to receive electromagnetic energy from an orbiting satellite.

Egress—Electromagnetic energy that escapes from a CATV plant.

Electromagnetic Energy—A form of radiant energy composed of both an electric field and a magnetic field.

Electromagnetic Induction—The property of inducing voltage in a coil of wire by causing magnetic lines of force to cut the turns of the coil.

Equalizer—A device used to modify the frequency response of a band of frequencies in order to produce a flat response curve.

Equalizing Pulses—Pulses placed in a television composite waveform to ensure proper vertical interlace.

Equatorial Orbital Arc—The area in space where the majority of communications satellites are located.

Exclusive Franchise—An area set aside for the exclusive use of a franchise holder (see "Nonexclusive Franchise").

Expansion Loop—An intentional loop made in coaxial cable to allow for expansion and contraction of the cable due to temperature changes.

FCC—See "Federal Communications Commission."

Federal Communications Commission—A governmental body whose responsibility is to regulate the use of the electromagnetic spectrum.

Feeder Cable (Line)—The distribution cable between the trunk line and the subscriber drop.

Fiber-Optic Cable—Cable made up of small glass fibers that carry modulated light energy from point to point.

Field Strength Meter—An instrument used to measure the signal strength of CATV signals.

Figure-8 Cable—A term used to describe integrated messengered coaxial cable.

Filter—An electromagnetic circuit that accepts or rejects a band of frequencies.

Fixed Receiver—A satellite receiver tuned to only one satellite transponder.

Flooding Compound—A waterproofing material that is placed between the shield and the jacket of coaxial cable.

FM—See "Frequency Modulation."

FM Transmitter—A transmitter that transmits a frequency-modulated (FM) carrier wave.

Footprint—The area on the earth that receives the majority of the signal from a communications satellite.

Franchise—An agreement between a franchising authority and a cable system to provide cable service.

Franchising Authority—A community that gives a cable system authority to sell their services within that community.

Frequency—The number of complete cycles occurring in a given time span. The number of times an electromagnetic wave repeats in 1 s.

Frequency Modulation—The process of causing the frequency of a carrier wave to vary with variations in the modulating signal.

Frequency Response—The change in gain within a device due to a change of frequency.

Front-to-Back Ratio—The ratio of power gain between the front lobe and the rear lobe of an antenna in decibels.

Fused-Disk Cable—A special type of coaxial cable that uses air as its dielectric and plastic spacers to support the center conductor.

Gain—An increase in power. The difference in level between the input and the output values expressed in decibels (see "Loss").

Geostationary—The appearance of being fixed at a location on or from the earth.

Geosynchronous—An object that has the same orbital period as the earth.

Ghosts—See "Reflections."

Graphics—Numbers, letters, symbols, pictures, or visual effects that are superimposed on a television picture.

Grid—A network of piping used to secure lights to be used in a television production.

Ground—A connection to the earth. A common tie point in electrical and electronic circuits.

Grounding—The process of connecting a conductor or device to the earth or to a common tie point.

Ground Wave—The electromagnetic energy radiated from an antenna that follows the surface of the earth.

Guy—A steel cable used to secure a utility pole.

Hand Tools—Tools used without an external power source to perform a job.

Hard Hat—A nonmetallic piece of headware used to protect a worker from injuries resulting from falling objects or from striking the head on sharp objects.

Hardware—Material used in fabricating or repairing a CATV system. Physical units and devices that make up a cable system.

Harmonics—Spurious signals generated by an electronic circuit that are multiples or submultiples of a desired frequency.

Head-End—The main hub of a CATV system where the signals from all sources are amplified, processed, and distributed to the subscriber.

Hertz—The basic unit of frequency.

Heterodyne—The process of mixing two signals together to obtain their sum or difference.

High Band—Television Channels 7 to 13.

High-Pass Filter—An electronic circuit designed to pass all frequencies above a certain frequency.

Homes Passed—The total number of homes that a cable system can serve within its franchise area (see "Penetration").

House Drop—The coaxial cable that extends from the feeder line tap-off device to the subscriber's set.

HRC (Harmonically Related Carriers)—A channel spacing scheme that places the television station's picture carrier on even numbered frequencies 6 MHz apart.

Hub—The head-end. A head-end slaved to a master head-end. Slaved head-ends are connected to the master head-end by supertrunk or by microwave transmissions.

Hyperband—A band of frequencies between 300 and 450 MHz used to provide channels for cable television use.

Hz—An abbreviation for hertz.

IF—See "Intermediate Frequency."

Impedance—The total opposition that a circuit offers to alternating-current (ac) flow.

Impedance Matching—The use of a device to match two lines whose impedances are different values (see "Matching Transformer").

Ingress—The unwanted introduction of spurious electromagnetic energy into CATV cable.

Insertion Loss—The loss of signal due to the insertion of a device into CATV lines. Usually expressed in decibels.

Installer—An individual who installs the subscriber drop cable from the tap-off device to the subscriber's television set.

Interconnect—The connection of the head-end to its hubs. The electrical connection between two circuits. The connection of two or more cable systems.

Interference—Any electrical or electromagnetic signal that causes an unwanted response.

Integrated Messengered Cable—Coaxial cable with a steel wire or cable embedded into its jacket. The steel wire or cable is used to support the weight of the cable.

Intermediate Frequency—The resulting frequency when two frequencies are heterodyned. The intermediate frequency is the difference frequency.

Intermodulation—The interaction between two or more signals. Intermodulation produces many multiples and submultiples of the individual signals.

IRC (Incremental Related Carriers)—A channel spacing scheme that increases standard Channels 5 and 6 by 2 MHz to provide an additional channel above standard Channel 4.

Jacketed Coaxial Cable—Coaxial cable that has a PVC covering to protect it from the elements.

Joint-Use Pole—A utility pole that accommodates telephone, power, and CATV services.

Laser (Light Amplification by Stimulated Emission of Radiation)—A device used to force light energy into a narrow, intense beam of coherent light.

Lashed Cable—Coaxial cable, usually unjacketed, that is bound (lashed) by a thin steel wire to the strand cable.

Lineman—An individual who constructs, repairs, and maintains a CATV plant.

Line-Extender or Distribution Amplifier—An amplifier used in the feeder line to amplify CATV signals.

LNA—See "Low-Noise Amplifier."

LNB (Low-Noise Block Converter)—A combination of a low-noise amplifier and a block converter.

LNC (Low-Noise Converter)—A combination of an LNA and a standard-type down converter.

Load Impedance—The impedance offered by the load circuit.

Lobe—An area of maximum energy within an antenna pattern.

Local-Origination Programming—Programming on access channels.

Logarithm (log)—A mathematical process that permits the expression of large or small quantities as a number raised to a power.

Loss—A decrease in power. The difference in level between the input and output values expressed in decibels (see "Gain").

Low Band—Television Channels 2 to 6 (see "High Band").

Low-Noise Amplifier—An amplifier placed at the focal point of a parabolic antenna to amplify the weak signals from satellite transponders.

Low-Pass Filter—An electronic circuit designed to pass all frequencies below a certain frequency.

Make-Ready—The process of preparing utility poles for the installation of CATV cables.

Main Trunk Line—The trunk cable between the head-end and the feeder cables (see "Trunk Cable").

Matching Transformer—An impedance matching device used to match the 75-Ω impedance of the coaxial cable to the 300-Ω input impedance of the television receiver.

MDS—See "Multipoint Distribution System."

Messenger Cable—See "Strand Cable."

Messengered Drop Cable—Drop cable with an integrated messenger wire (see "Integrated Messengered Cable").

MHz—An abbreviation for megahertz. One megahertz is equal to one million hertz.

Microwave—A band of frequencies (1000 MHz and up) used for point-to-point transmission of signals.

Midband—A band of frequencies between television Channels 6 and 7. The midband extends from 120 to 174 MHz.

Midspan—A method of running subscriber drop cable so that it does not cross property lines. Midspan connections are made by running the subscriber drop cable back along the feeder cable and then into the subscriber's home.

Milliampere—One thousandth of an ampere.

Millivolt—One thousandth of a volt.

Mixer—An electronic circuit used to heterodyne two signals to produce an intermediate frequency.

Modulation—The process of putting intelligence on a carrier wave.

Monitor—A device used to check the state of something else. A device resembling a television set.

MSO (Multiple-System Operator)—An owner of two or more CATV systems.

Multiplexer—A device that allows two or more signals to be sent over the same transmission line simultaneously.

Multipoint Distribution System—A method using microwave transmissions to send pay channel signals to hotels and homes not connected to CATV.

Multitap—A device that allows two, four, or eight subscriber drop cables to be connected to a feeder line without a mismatch.

New Build—A portion of a CATV system that is almost operational. Additional coaxial cable added to an existing CATV system.

Noise—Random bursts of energy that cause interference in a television picture (snow).

Noise Figure—The ratio of noise at the output of an amplifier compared to thermal agitation in the resistance of the signal source.

Nonexclusive Franchise—A franchise that allows others to sell their services within the franchise area (see "Exclusive Franchise").

Nonsynchronous—Not synchronized with the orbital period of the earth.

Off-the-Air-Signals—Television or radio signals that a subscriber may receive over the air.

Ohm—The unit of opposition to current or signal flow.

Orbit, Synchronous—See "Geosynchronous."

Ordinance—A regulation or law passed by a community for its protection.

Overbuild—A situation where two or more cable companies run lines into the same area for the purpose of competition.

Parabolic Reflector Antenna—A metallic reflector in the shape of a parabola with an antenna mounted at the focal point of the parabola.

Passive Device—An electronic circuit or network that takes signal energy from a CATV system (see "Active Device").

Pay Cable—See "Pay TV."

Pay per View—A system where the subscriber pays an additional charge for an extra special program.

Pay TV—Programming that subscribers pay extra for. Examples are HBO, Showtime, and Cinemax. Programming other than Basic cable service.

Pedestal—A small housing for access to underground cables. Pedestals are available in a variety of sizes.

Penetration—The ratio of subscribers to the number of potential subscribers (see "Homes Passed").

Piezoelectricity—Energy generated by mechanically stressing certain cystals.

Pilot Frequency—Generally two frequencies used to furnish the AGC and ASG circuits with a reference value.

Polarization—The process of making electromagnetic energy follow a pattern such that its strength lies either perpendicular or parallel to the surface of the earth.

Pole Attachment Rate—The rate per year that a utility pays to the owner of a joint-use pole for allowing attachment.

Power Tools—Tools energized by air (pneumatics), fluids (hydraulics), or electricity.

Preamplifier—See "Antenna Preamplifier."

Premium Service—See "Pay TV."

Programming—The news, entertainment, and information provided to a CATV subscriber.

Public-Access Channels—See "Access Channels."

PVC—Abbreviation for polyvinylchoride.

Radiation—The propagation of energy through space by an antenna.

Raster—The illuminated area on a television screen.

Reflections (Echoes)—Electromagnetic energy that does not arrive at the receiving antenna by a direct route, but rather bounces off nearby objects. Sometimes called a "ghost."

Request for Proposal—A set of forms that spell out the requirements for application for a CATV franchise.

Resistance—The opposition to current flow. The unit of resistance is the ohm.

Return Loss—The ratio between the energy sent out to the amount that returns. Return loss is measured in decibels.

RF—Radio frequency.

RF Carrier—A fixed radio frequency generated by an oscillator or a transmitter.

RFP—See "Request for Proposal."

Safety Strap—A belt used to secure a climber to a pole or structure.

Satellite—An orbiting receiver-transmitter (transponder) used to relay programming from ground stations to cable systems.

Scrambling—A method of preventing unauthorized people from receiving a program by insertion of a carrier that renders the program unintelligible.

Screw Anchor—A device that screws into the ground and is used to secure a utility pole.

Second-Order Beat—Unwanted interference that results from intermodulation of two signals.

Second-Order Harmonic—A multiple or submultiple of a fundamental frequency. Second-order harmonics are either one-half or twice the value of the fundamental frequency.

Sheath, Coaxial Cable—The outer conductor of coaxial cable. Sheaths for trunk and feeder cables are solid, while those for drop cable are flexible.

Signal—The intelligence sent over a communication system.

Signal Combiner—A device used to allow many individual channels to be placed on one transmission line.

Signal Conversion—The process of taking a signal at one frequency and changing it to another frequency.

Signal Distribution System—A network of active and passive devices that allows subscribers in various parts of the community to receive cable programming.

Signal Level—The magnitude of the signal at some point in the signal distribution system to a standard. Signal levels are measured in dBmV.

Signal Splitter—See "Splitter."

Signal-to-Noise Ratio—The ratio between the magnitude of the signal to that of the noise. Signal-to-noise ratios are expressed in decibels.

Signal Trap—A passive device that eliminates a band of frequencies. A device used to prevent a nonsubscriber from receiving a Premium channel.

Slope—The difference in gain between the lowest and the highest frequencies in the cable system.

SMATV—An abbreviation for satellite master antenna television. An SMATV system is a small CATV distribution network for an apartment complex.

S/N—(see "Signal-to-Noise Ratio").

Span—The distance between utility poles, taps, or distribution amplifiers.

Splitter—A device that allows a single input to be separated into many parts without appreciable loss or mismatch.

Standby Power Supply—An emergency source of energy used to power CATV equipment in the event of a power outage.

Strand or Messenger Cable—A steel cable used to hold trunk and feeder cables. Strand cable is secured to utility poles by clamps, and coaxial cable is lashed to it.

Structural Return Loss—A method of determining the quality of coaxial cable through the use of electronic test equipment.

STV—An abbreviation for subscriber television. In an STV system, scrambled signals are broadcast and only those with decoders can receive them.

Subband—A band of frequencies that extend from 5 to 32 MHz that is used to carry the return signals from subscribers.

Subscriber—An individual who pays for CATV programming.

Subscriber Drop Cable—See "Drop Cable."

Suck-out—The result of the center conductor within a

connector pulling away from its contact because of contraction of the coaxial cable.

Superband—The band of frequencies from 216 to 300 MHz used to provide channels for cable television.

Superstation—An independent television station that sends its programming to satellites for rebroadcast as well as over the air.

Supertrunk—A trunk cable that supplies signals to a slave head-end (hub).

Tap—A passive device used to provide signals from a feeder line to subscribers.

Telecasting—See "Broadcasting."

Television Receive-Only—An earth station capable of television reception only. Cable systems ground stations are television receive-only stations.

Terminator, Cable—A device to match the end of a cable run with its characteristic impedance.

Third-Order Beat—Unwanted interference resulting from intermodulation of three signals.

Third-Order Harmonic—A multiple or submultiple of a fundamental frequency. Third-order harmonics are either one-third or three times the value of the fundamental frequency.

Tier—A level of cable service. Generally, Basic cable constitutes one tier and each Premium channel constitutes another.

Tilt—See "Slope."

Transmission—The conveying of electromagnetic energy from point to point.

Transmission Line—A system of conductors used to transfer signals from one location to another.

Transmitter—Equipment used to generate electromagnetic energy and send it to an antenna.

Transponder—An electronic device on a satellite that receives and then retransmits CATV signals.

Triple Beat—A third-order beat that causes interference within a cable system.

Trunk Amplifier—An amplifier used in the trunk line of a cable distribution system.

Trunk Cable—Coaxial cable used to carry CATV signals from the antenna site to the head-end or to transport the signals to the feeder lines.

Trunk Line—See "Trunk Cable."

Trunk Station—A housing containing a trunk, bridging, and return signal amplifier and associated circuitry.

Turn-on Crew—A crew of technicians who ensure the integrity of a distribution system, align the amplifiers, and perform preliminary tests on a new cable system.

TVRO—See "Television Receive-Only."

Two-Way Capability—The ability of a cable system to provide for amplification of signals from subscribers and to provide subscribers with signals.

UHF—The band of frequencies between 300 and 3000 MHz.

Underground Plant—A cable system that utilizes buried cable instead of aerial cable for the distribution of their signals.

Uplink—The communication signals from ground stations to the satellite (see "Downlink").

Upstream—The signals from subscribers to the head-end of a CATV system.

Vault—A concrete container that houses coaxial cable as well as active and passive devices that are part of an underground CATV distribution system.

VHF—The band of frequencies between 30 and 300 MHz.

Video—The picture portion of a television signal.

Voltage—The electrical pressure that exists between charged bodies. Voltage is measured in volts, millivolts, and microvolts.

Voltage Standing-Wave Ratio—The ratio of the amplitude of the electric field at a voltage maximum to that at an adjacent voltage minimum.

VSWR—See "Voltage Standing-Wave Ratio."

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